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DISPENSER CATHODE

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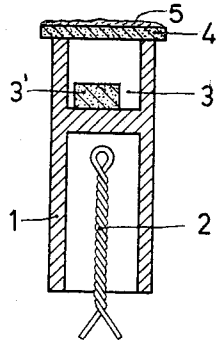

FIG.1

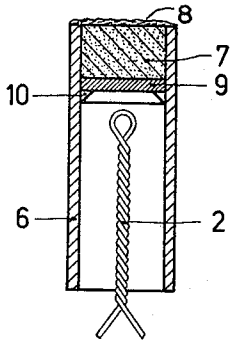

FIG.2

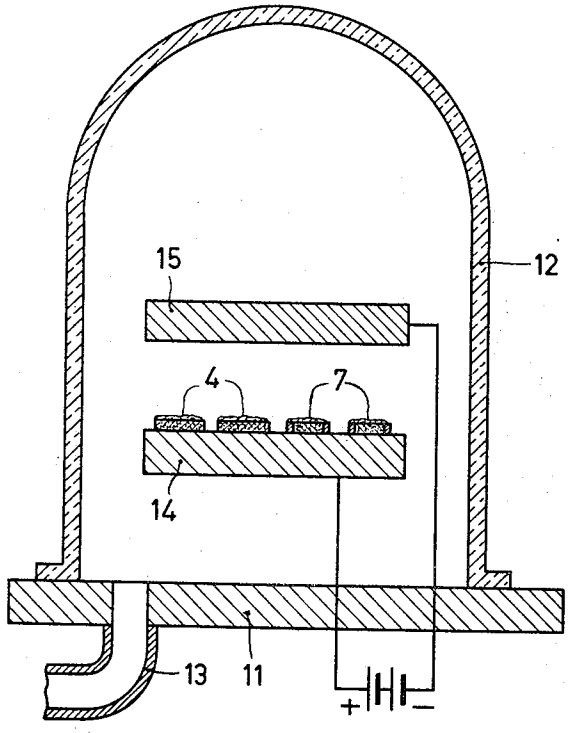

FIG. 3

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DISPENSER CATHODE

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6 Claims. (Cl. 313—346)

ABSTRACT OF THE DISCLOSURE

A dispenser type cathode comprising a refractory metal matrix of tungsten or tungsten-molybdenum in reactive relationship with an alkaline earth metal compound which will supply free barium to the emitting surface of the matrix. A thin porous layer of a refractory metal having a work function higher than that of tungsten covers the emitting surface. The layer metal is selected from the group of osmium, iridium, ruthenium, and rhenium. The resultant cathode exhibits increased electron emission at the same temperature, or the same electron emission at a lower temperature, than that of a comparable cathode without the layer.

This invention relates to a dispenser cathode, and in particular to a dispenser cathode in which the emitting surface is constituted by a surface of a porous, refractory-metal matrix or body in the pores of which or behind which alkaline earth metal compounds are provided.

Cathodes of the foregoing type are described, for example, in United States Patents 2,543,728, 2,700,000, 2,700,118, 2,971,246, and 3,201,639, the contents of which patents are hereby incorporated by reference. Two types of cathodes are described in these patents and application, one of which is known in the art as the cavity-type or L-cathode, and the other of which is known as the impregnated cathode. In both cases, the emissive surface is a surface of a densely-sintered, porous, refractory-metal body with a density in the range of 70–85% so that the pores are interconnected. In the cavity-type cathode, the alkaline earth metal compounds, which generally are barium aluminates or barium calcium aluminates, are located in a cavity behind the refractory-metal matrix. In the impregnated cathode, these compounds are melted into to impregnate the refractory matrix. The matrix is generally formed to tungsten. During operation, when such cathodes are heated at a temperature of the order of 1050° C. brightness, a reaction takes place between the tungsten and the aluminates resulting in the generation of barium and barium oxide vapor, which flow through the pores of the matrix to form on the emitting surface of the refractory matrix a barium monolayer. It is believed that a dipole layer of barium-on-oxygen-on-tungsten is established on the emitting surface. While the work function of the pure tungsten is approximately 4.5, with the barium monolayer, the work function falls to approximately 2.1, and as a consequence at the indicated temperature a very high level of emission density results. Experience has shown that the emission capability of such cathodes roughly doubles for every 50° C. increase in temperature.

Such cathodes as above described are widely used in microwave tubes which require long life and high current densities, as well as high resistance to back bombardment, poisoning, arcing, and so forth. In one particular microwave tube, a disc-seal triode, which is described in "Philips Technical Review," vol. 18, No. 11, 1956/57, pp. 317 to 348, the cathode is spaced very close to an adjacent grid electrode composed of very fine parallel wires. It has been found that one of the limitations on the life-time of such tubes is the evaporation of barium or barium oxide from the surface of the cathode, some of which deposits on the fine grid wires, resulting in an increase in their effective diameter and a reduction in their effective spacing. This causes a change in the transconductance of the tube and ultimately requires replacement of the tube. In order to reduce the level of evaporation products from such cathodes, it would be desirable to reduce the operating temperature of the cathode, since the evaporation rate is an exponential function of the temperature. However, the emission level from the cathode is also a function of the temperature, and, as explained before, a reduction of 50° C. in the operating temperature reduces the emission level by roughly 50%. Yet, the tube design requires for satisfactory operation a certain minimum level of emission.

One object of the invention is to provide a dispenser cathode of the type described capable of a high level of electron emission at reduced temperatures.

A further object of the invention is a cathode capable of a high level of electron emission whose lifetime is substantially increased.

Still a further object of the invention is an improvement in the operating properties of a dispenser cathode of the type described at the expense of only a minor increase in the cost of its manufacture.

The foregoing objects are achieved with our novel dispenser cathode which will now be briefly described. It is known that the emission level from a cathode is a function of the work function of the emitting surface, with the lower the work function the higher the emission level. We have found it possible to effect a substantial reduction in the work function of the emitting surface of the aforedescribed dispenser cathode, at little additional cost, by providing on it a porous coating of certain selected refractory metals whose work function is actually higher than that of tungsten. This takes advantage of the fact that the overall work function of the emitting surface containing the barium layer on the refractory metal as a substrate is inversely proportional to the work function of the pure substrate itself. In other words, by employing a material for the refractory matrix surface that exhibits a higher work function than of tungsten, the overall work function of that surface with the barium monolayer is less than that of the comparable surface with tungsten. While there are a number of refractory metals which fulfill this requirement of exhibiting a higher work function than that of tungsten, we have found that only certain of these are useful for the intended purpose. In particular, we have found that the desired results are achieved by employing for the coating one of the following four metals: osmium, iridium, ruthenium, and rhenium. Thus, a cathode according to our invention comprises essentially the same cathode using tungsten or tungsten-molybdenum which is described in the prior art and has been widely used throughout the world for many years, with the addition only of a thin coating on the emissive surface only of one of the above-mentioned metals. Amazingly, the simple addition of a thin coating of one of those metals on a standard dispenser cathode of the type described, which can be carried out at very little additional cost, has resulted in a reduction in operating temperature of the cathode by as much as 125° C. This is roughly the equivalent of increasing the emission level of the cathode at the former temperature by between 300% and 400%, which is truly a remarkable

result of this extremely minor change in the construction of the cathode.

What is surprising about our invention is that rhenium, one of the coating metals in accordance with our invention, has been suggested many times in the past as a substitute for the tungsten for the matrix. Experiments carried out in the manufacture of rhenium impregnated cathodes, oddly enough, have not resulted in a satisfactory cathode which exhibited higher emission levels than the corresponding tungsten cathode. Many experiments with rhenium have resulted at best in a short time increase in emission, but a very much shorter lifetime of the cathode, which made it unusable commercially. In addition, the expense of a cathode with the entire disc of rhenium would be prohibitive. A recent investigation of a rhenium cathode, described in the Mitsubishi Denki Laboratory Reports, Report 4, No. 2, April 1963, pages 253 to 264, indicated that the emission level of a rhenium cathode was inferior to that of the corresponding tungsten cathode. Yet, we have found that when the rhenium is provided as a porous coating on top of the tungsten matrix, then a considerable increase in emission is obtained, which thus allows the cathode to be operated at a reduced temperature, which thus prolongs its lifetime.

It has also been suggested in the past to include platinum in the tungsten matrix to alloy with the barium and prolong the cathode's lifetime. Platinum is excluded from the scope of our invention, because our experience has been that platinum in time poisons the emission from these tungsten cathodes and is undesirable. The same applies to palladium, and we therefore also exclude palladium from the scope of our invention. For completeness sake, it is noted that the work functions of the four metals employed in our invention as the coating material are as follows: rhenium is 5.1; iridium is 5.4, and ruthenium and osmium are 5.5–5.6. Therefore, we prefer to use osmium or ruthenium as the metal coating.

The invention will now be described in greater detail with reference to the accompanying drawing, in which:

FIG. 1 is a cross-sectional view of one form of a cavity-type dispenser cathode in accordance with our invention;

FIG. 2 is a cross-sectional view of one form of impregnated cathode in accordance with our invention;

FIG. 3 illustrates in cross-section a suitable apparatus for coating the refractory-metal matrix with the high work function metal by means of cathode sputtering.

Referring to FIG. 1, there is illustrated therein a typical cavity-type dispenser cathode as described in several of the aforementioned patents. It comprises a refractory metal support **1**, generally of molybdenum, which houses a heating filament **2** in its lower recess. The upper half of the support **1** contains a cavity **3** which is sealed off by a densely sintered, porous, refractory-metal matrix **4**, which is preferably of tungsten, but which also may be composed of an alloy of tungsten and molybdenum. The pores of the body **4** are interconnected, and the density is approximately 80%. Reference is made to United States Patent No. 2,721,372 for a suitable technique for making such porous refractory bodies with a high density. The body **4** may be mounted to seal off the cavity **3** by means of a projection weld. Inside the cavity **3** is provided a mass **3'** of an emissive material, as described in the aforementioned patents. Preferably, the material includes a barium aluminate. A suitable composition is a mixture of 50% by weight of fine tungsten powder and 50% by weight of barium-calcium-aluminate, the latter of which has the composition $5BaO$, $2Al_2O_3$ and $3CaO$, (mole ratio) and is formed by fusing a mixture of the constituents or their corresponding carbonates to produce the desired aluminate. The compositions described in the aforementioned patents are also considered within the scope of our invention and may be used in place of the aluminate-tungsten mixture just described. It will further be noted that what has so far been described has been

fully taught in the prior art and in fact has been in wide commercial use.

The main feature of our invention is to cover this known prior art cathode with a thin porous layer of one of the metals, osmium, rhenium, ruthenium, or iridium. We prefer osmium or ruthenium because, as explained earlier, the higher the work function of the substrate, the lower the overall work function of the substrate covered with the barium monolayer. With osmium on the surface as the substrate, which is indicated by reference numeral **5** in FIG. 1, we have found that the emission level is between 300% and 400% higher than the same cathode omitting the osmium coating **5**, which is an extraordinary improvement considering the very minor change in its construction and the ease in its manufacture. There appear to be no critical limits to the thickness of the coating **5**. It should possess at least a minimum thickness to assure its preservation and prevent its loss by undue diffusion or evaporation, while the thickness should not be so great as to render it impermeable to the barium passing through the tungsten disc **4** and thus prevent its penetrating the coating to form the desired monolayer on its exposed surface. We have obtained satisfactory results with thicknesses between about 100 and 5,000 Angstroms units. It will be readily appreciated that such thin coatings are inherently porous or permeable to the barium or barium oxide vapor. The coating may be applied in many different ways. For example, it may be applied electrolytically, or by cathode sputtering in a glow discharge. Thus, we have applied a layer of rhenium of approximately 3,000 Angstroms thickness by immersing the tungsten body **4** in a bath containing an acid solution of potassium perrhenate as an electrolyte. This cathode exhibited a saturation emission of 15 amperes per sq. cm. at an optically measured temperature of 950° C., and a similar cathode exhibited a saturation emission of 65 amperes per sq. cm. at 1050° C. These values are considerably higher than the corresponding emission from the prior art tungsten cathode. A thicker coating which will still be porous, may be applied by spraying a slurry formed by fine powders of the high work function metal dispersed in a suitable vehicle, followed by sintering to bond the powder to the matrix, as described in a copending application, Ser. No. 363,580, filed Apr. 29, 1964.

Another cavity-type cathode of the type of FIG. 1 with as osmium metal coating produced the same emission at 925° C. as measured optically (true temperature approximately 975° C.) as did the same cathode without the osmium coating at 1050° C. measured optically (true temperature approximately 1120° C.). Because of this reduced temperature, the life of the cathode is considerably increased due to reduced evaporation, and as a further consequence in the disc-seal triode previously mentioned with a closely-spaced grid, the growth of the grid deposit is considerably diminished which prolongs the life of the tube.

FIG. 2 illustrates one form of an impregnated cathode in accordance with the invention as previously described. The major difference between it and the cavity-type cathode, illustrated in FIG. 1, is that the pores of the tungsten matrix **7** are now impregnated from the melt with the barium-calcium-aluminate of the 5:2:3 mole ratio previously described, and as specifically mentioned in U.S. Patent No. 3,201,639. In this case, no cavity is present as the emissive material is wholly contained in the pores of the matrix. However, the support **6** exhibits a similar shape, a molybdenum plate **9** below the impregnated disc **7** being used to prevent evaporation of the barium onto the heater **2**. Alumina **10** may be used to mount the molybdenum plate **9** within the cylinder **6**. The coating of osmium, ruthenium, iridium or rhenium is indicated by the reference numeral **8**. In this particular case, the layer **8** was ruthenium with a thickness of approximately 1,000 Angstrom.

FIG. 3 illustrates one very convenient sputtering technique for providing the metal coating on the surface of the matrix. The apparatus shown comprises a base plate **11** supporting a bell jar **12** which may be exhausted through an exhaust tube **13** connected to a suitable vacuum system (not shown). Within the bell jar is mounted two plates **14** and **15** of the metal of the coating. In this particular case, the coating metal was iridium, and the plates would be of iridium. Suitable dimensions for the plates would be 3 cm. in diameter with a spacing of approximately 6 mm. Several of the porous tungsten bodies **4** are placed on the lower iridium plate **14** as shown. In addition, for an impregnated cathode, the body **7** would be employed as illustrated, in which case they would have already been impregnated with the aluminates. The upper iridium plate **15** serves as a cathode, and the bottom plate **14** as an anode. The bell jar is filled with a noble gas such as argon at a low pressure of approximately 1 mm. mercury, and then a voltage of approximately 600 volts is applied between the plates **14** and **15** to establish a glow discharge therebetween with a current intensity of approximately 20 milliamperes, with the plate **15** serving as the cathode. The ion bombardment of the cathode **15** causes evaporation or sputtering of iridium atoms which deposit onto the tungsten matrices **4** and **7** to form the desired coating. Due to the particular arrangement, very little of the atomized iridium is lost on the wall of the bell jar **12**. From time to time, plates **14** and **15** may be interchanged. In about 15 minutes, an iridium layer of about 1,000 Angstroms is deposited on the matrices **4** and **7**. A similar technique may be used for osmium.

It will be appreciated from the foregoing that by only a very minor change in the construction of a standard dispenser cathode, a startling and unexpected improvement in properties results. Improvements in emission levels as much as 400% have been achieved. To maintain the same emission level as formerly obtained, the cathode of the invention may be operated at a much lower temperature, resulting in a substantial reduction in the evaporation rate of the active material and thus a substantial improvement in the lifetime of the cathode.

While we have described our invention in connection with specific embodiments and applications, other modifications thereof will be readily apparent to those skilled in this art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A dispenser cathode comprising a porous body of a refractory metal selected from the group consisting of tungsten and tungsten-molybdenum alloys, an alkaline earth metal compound in reactive relationship with the body and capable when heated of releasing free barium metal which is capable of flowing through the pores to form a layer of barium on a surface of the body intended to serve as an emissive source of electrons, a thin layer of a refractory metal having a work function higher than that of pure tungsten and selected from the group consisting of osmium, ruthenium, iridium, and rhenium on only the surface of said body from which electron emission is desired, said layer being porous to the barium flowing through the pores of the body, and means for heating said body at an elevated temperature whereby said cathode exhibits substantially the same emission level as a comparable cathode without the higher work function layer but at a much lower temperature.

2. A dispenser cathode as set forth in claim **1** wherein the cathode is a cavity-type cathode with the alkaline earth metal compound located in a cavity sealed off by the porous body.

3. A dispenser cathode as set forth in claim **1** wherein the cathode is an impregnated cathode with the alkaline earth metal compound melted into the pores of the porous body.

4. A dispenser cathode comprising a densely-sintered porous body of a refractory metal selected from the group consisting of tungsten and tungsten-molybdenum alloy, an alkaline earth metal compound in reactive relationship with the body and capable when heated of releasing free barium metal which is capable of flowing through the pores to form a layer of barium on a surface of the body intended to serve as an emissive source of electrons, a thin layer of a refractory metal having a work function higher than that of pure tungsten and selected from the group consisting of osmium, ruthenium, iridium, and rhenium on only the surface of said body from which electron emission is desired, said layer being porous to the barium flowing through the pores and having a thickness between about 100 and 5000 Angstroms, and means for heating said body at an elevated temperature whereby said cathode exhibits substantially the same emission level as a comparable cathode without the higher work function layer but at a much lower temperature.

5. A dispenser cathode as set forth in claim **4** wherein the alkaline earth metal compound includes barium aluminate.

6. A cathode as set forth in claim **5** wherein the compound is a barium-calcium-aluminate.

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