United States Patent

[11] **3,558,966**

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[21] Appl. No. **619,690**
[22] Filed **Mar. 1, 1967**
[45] Patented **Jan. 26, 1971**

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[54] DIRECTLY HEATED DISPENSER CATHODE

5 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **313/346,**
313/311, 313/341, 313/345

[51] **Int. Cl.** **H01j 1/14,**
H01h 1/04, H01j 19/06

[50] **Field of Search** 313/311,
346, 337, 341

[56] **References Cited**

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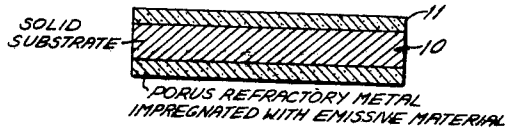
ABSTRACT: A directly heated dispenser-type cathode for microwave tubes and the like, the cathode being formed by a solid electrically conductive substrate, such as tungsten wire, the surface of which has bonded thereto a porous layer of a refractory metal whose pores are impregnated with an electron-emissive material having a low work function, such as barium oxide.



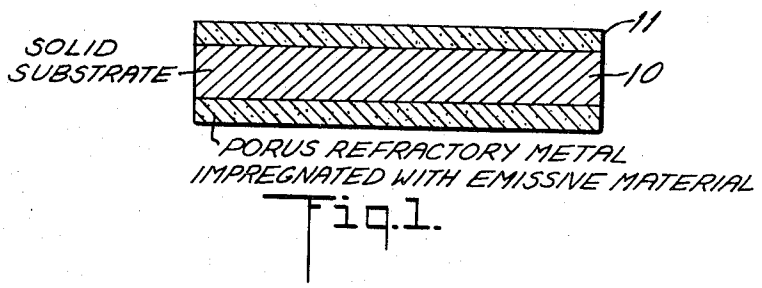


Fig. 1.

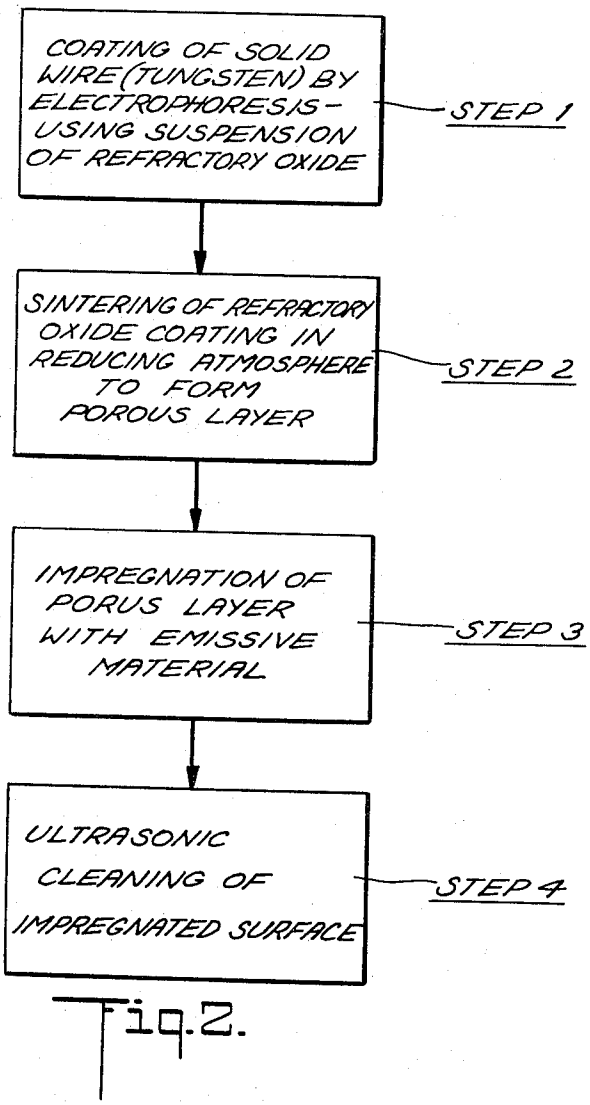


Fig. 2.

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DIRECTLY HEATED DISPENSER CATHODE

This invention relates generally to electron-emitting sources, and more particularly to a directly-heated dispenser cathode adapted for use in microwave tubes, such as magnetrons and the like, as well as for other electronic instruments employing electron-emitting sources.

Most microwave tubes are designed to deliver moderate to high power in the megawatt range. The electron beams for such tubes are characterized by high-voltage, high current operation. Among the problems encountered in microwave tubes are the limitations imposed by the electron-emitting source, which may be an indirectly or a directly-heated cathode. These limitations are the maximum allowable current density and the effect on the cathode structure of ion bombardment. In some instances, cathodes which require high operating temperatures are not desirable, for these temperatures make necessary auxiliary cooling equipment and other special accessories which may be objectionable or costly.

One well-known type of electron-emitting source commonly used in microwave tubes is the thoria-type, directly heated cathode. This cathode is formed by sintering a pressed mixture of powdered thorium oxide and powdered tungsten or molybdenum, to form a blank which is then extruded or otherwise worked. Heating of the cathode is accomplished by passing a current therethrough which raises the surface temperature to an emissive level. Because of the high work function of the cathodic material, in operation the surface thereof must be at a temperature of about 1600° C. Such directly heated thoria-type cathodes are capable of producing high current densities and have advantages over conventional oxide-coated cathodes wherein a base metal is coated with oxides of barium and strontium, for they are able to withstand high-voltage ion bombardment.

Another well-known type of cathode structure is the indirectly-heated dispenser type, such as are disclosed in prior U.S. Pat. Nos. 2,700,000, 2,813,807, and more recently in U.S. Pat. No. 3,118,080, issued on Jan. 4, 1964 to O. G. Koppius. Dispenser cathodes of the indirectly-heated type contain a large amount of low work-function semiconductor material impregnated in a porous body, which is usually of sintered tungsten. During operation, a large amount of active metal, such as barium, is produced, which diffuses to the emitting surface and continuously replenishes the active metal which has been evaporated or sputtered. As compared to the standard oxide-coated cathode, the dispenser cathode is much less sensitive to ion bombardment, and higher current densities are feasible.

Both the thoria-type of directly-heated cathode and the dispenser type of indirectly-heated cathode are superior in most respects to the standard oxide-coated cathode for microwave tube applications. The thoria-type has the advantage over the dispenser type in being easier and cheaper to fabricate. On the other hand, the thoria-type becomes extremely brittle after processing, it contaminates easily at low temperature, and does not function well below 1,400° C., whereas the dispenser type is mechanically very rugged, it resists contamination, and can operate successfully at a temperature level as low as 900° C. Among the advantages of low temperature operation are reduced input power requirements, a simplified supporting structure, as well as the use of less exotic metals in the region surrounding the cathodes.

Accordingly, it is the main object of the present invention to provide a dispenser cathode which is directly heated, and which possesses the advantages both of the directly heated thoria-type cathode and of the indirectly heated dispenser type, without the drawbacks incident to such cathodes.

More specifically, it is an object of this invention to provide a directly heated dispenser cathode constituted by a solid filamentary wire coated with a porous refractory metal impregnated with an emissive material having a low work function.

Among the significant advantages of a directly heated dispenser cathode in accordance with the invention are fast heatup time, fast activation, and low gas evolution, as well as long life. Inasmuch as the directly heated dispenser cathode may be in filamentary form and makes use of a ductile substrate metal, it may be coiled or otherwise handled in the manner of a directly heated filament for use in magnetrons, klystrons, traveling wave and backward wave tubes and in other microwave tubes, as well as in masers, lasers and in mass spectrometers and in other electronic instruments. A further advantage of the invention is that the dispenser cathode may be fabricated at relatively low cost compared to conventional dispenser cathodes.

Briefly stated, these objects are attained by a fabricating technique wherein a substrate of a solid, electrically conductive metal has formed thereon a porous layer of refractory metal, which layer is impregnated with emissive material. Preferably, the porous layer is formed by cataphoretic coating of the substrate by a reducible oxide mixture, which is thereafter sintered in a reducing atmosphere.

Alternatively, the porous layer may be formed by coating the substrate with a mixture of the refractory metal in powder form and an organic binder, this being accomplished by spraying, dipping or painting, and then sintering this coating in vacuum or in a reducing atmosphere. Another method for forming the porous layer is by high-temperature spraying of the metallic or reducible oxide powder onto the substrate under a neutral or reducing atmosphere, whichever is appropriate. In all instances, a porous layer of refractory metal is formed on the substrate and bonded thereto, which layer is then impregnated with the emissive material having a low work function.

For a better understanding of the invention, as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 is a sectional view of a directly heated dispenser-type cathode in accordance with the invention; and

FIG. 2 is a flow chart of a preferred technique for making this cathode.

Referring now to FIG. 1, a directly heated dispenser cathode in accordance with the invention is constituted by an electrically conductive substrate **10** of solid, nonporous metal, having a porous layer **11** of a refractory metal, which is sintered and bonded to the substrate, the pores of the layer being impregnated with a low-work function material.

In practice, the substrate **10** may be a solid wire or a body of any formed or machined configuration suitable for cathode structures, the wire or body being of tungsten, molybdenum, rhenium, or any suitable combination of refractory metals. When wire is used, it may have a diameter of 0.001 inch or greater.

Preferably, the substrate is constituted by a tungsten alloy or other refractory metal characterized by high strength and good ductility, and hence one which is easy to bend or otherwise handle. Theoretically, it would be possible to make a directly heated dispenser cathode by impregnating a porous substrate of electrically conductive material with a work function lowering ingredient, but the resultant cathode would be of low strength and hence difficult to handle. Moreover, the resistivity of the cathode would be unstable because of high-temperature electrolysis.

The porous layer on the substrate is preferably formed of refractory metal oxides, such as WO_3, MoO_3, or any combination of the reducible oxides, which when sintered in a reducing atmosphere, provides the desired layer. The emissive ingredients, which are used to impregnate the porous coating, may be any of those disclosed in the above-cited patents, such as alkaline oxides, carbonates or their derivatives, which will decompose to an oxide. Among the usable impregnates are BaO, CaO, Al_2O_3, 3, SrO, MgO, and/or rare earth oxides, either their carbonates or their derivatives, in any appropriate emissive combination. The invention encompasses any known form of emissive material of the type usable in a porous matrix to provide a dispenser-cathode action.

METHOD I

A tungsten-rhenium wire (3 percent Re by weight) of 0.001 inch diameter, is first coated with WO_3 using an electrophoresis technique. In this technique (step **1**) the coating is applied to the wire by passing it through or dipping it in a suspension of the coating material in a suitable container, an electric field being established in the suspension by a direct voltage connected between the wire and an electrode immersed in the suspension or the container itself, if it is conductive. In plating, the wire acts as an anode and the electrode or the container as a cathode. The following suspension is used:

WO3	50 g.
NH4Cl	1 g.
H2O	100 cc.

The NH4Cl acts as an ion carrier. Alternatively, $MgCl_2$ or any other ion carrier may be used for this purpose. To obtain a coating thickness of .010 inch or more, the voltages and other conditions are:

Voltage	75 v.
Current	0.3 amp.
Time	5 seconds

After the coating is formed, the coated wire is sintered (step **2**) in a reducing atmosphere (hydrogen) under temperature conditions not going above 2,300° C. for 10 minutes, or at any time-temperature schedule to reach the desired density and to effect bonding of the coating to the substrate. One suitable schedule is as follows:

Temperature	Time
850° C.	1 minute
1,500° C.	3 minutes
2,100° C.	3 minutes

If thicker layers are desired, the coated and sintered wire may be again coated and resintered until the desired thickness is attained.

The impregnant (step **3**) is then applied to the sintered porous layer, using electrophoresis, spraying or dipping. After this application, the entire body is then heated in a suitable furnace to a temperature which is about 100° C. above the melting point of the impregnant but not in excess of 2,300° C. to cause the impregnant to fill the pores. One preferred form of impregnant is $BaO:CaO:Al_2O_3$, having a 4:1:1 mole ratio. The thickness of the layer and the amount of impregnant used depends on the intended life of the cathode.

Excess surface impregnant is then removed by ultrasonic cleaning techniques (step **4**) which act to dislodge any surface material outside of the pores in the layer. Abrasive or chemical techniques may also be used for this cleaning step.

A directly heated dispenser cathode made in accordance with the above steps, was found to have the following useful properties:

A. Very low gas evolvement (2×10^{-6} mm. hg. 3 minutes at 1,050° C.)

B. Fast heatup time (1,050° C.—less than four seconds)

C. Fast activation (15 minutes at 1,100° C., regardless of total length of filament cathode)

D. High current density (average current of two amperes per $cm.^2$ at 900° C. cathode temperature, with 50 v. across anode having 0.030 inch spacing.)

E. Long life (minimum of 1,000 hours at 900° C. in 1×10^{-7} mm. hg.

METHOD II

This method essentially differs from method I in the manner in which the porous layer of refractory metal is formed on the substrate. A slurry formed of the selected refractory metal, such as tungsten or molybdenum powder, mixed with an organic binder in an amount to obtain a desired degree of fluidity, is applied to the substrate by dipping, painting or spraying. A suitable slurry for this purpose is composed of 100 gms. of tungsten, 35 gms. of acetone/amyl-acetate, and 5 gms. of pyroxylin.

The coating thus formed is then sintered in a neutral or reducing atmosphere to drive off the volatile binder and to sinter the metallic particles. Thereafter the porous layer is impregnated as in method I. This method is suitable for solid wire substrates or pieces having large uniform surfaces, but in more complex shapes, it has the drawback of producing uneven coatings. Also, a certain degree of gas evolution arises by reason of carbon residue from the binder material. The presence of such residue may be minimized by using a binder such as methyl methacrylate which leaves little residue.

METHOD III

High-temperature spraying may be effected by single-pass mixing of emissive material with the refractory metal powders to obtain the desired composition, and using a flame temperature range of 1,200° C. to 1,800° C. onto the substrate. Alternatively, multiple-pass, high-temperature spraying may be used wherein the metal powders or oxides go through a reducing carrier gas to form a porous layer at the temperature range of 1,600° C. to 2,300° C., the emissive material then being sprayed at 100° C. above its melting point, and below 2,300° C.

Thus in the dispenser-cathode structure in accordance with the invention, the substrate acts not only mechanically to support the dispenser components, but also as an electrical heater therefor. In wire form, this directly heated dispenser cathode may be handled as a thoriated filament without however encountering the drawbacks of such filaments.

While there have been shown and described preferred embodiments of directly heated dispenser cathodes in accordance with the invention and various techniques for fabricating such cathodes, it will be appreciated that many changes and modifications may be made therein without, however, departing from the essential spirit of the invention as defined in the annexed claims.

We claim:

1. A directly heated dispenser cathode structure comprising:

a. a solid substrate of electrically conductive material, said substrate being formed of tungsten wire capable of being coiled;

b. a layer of porous material bonded to said substrate and formed of refractory metal, said layer material being selected from a class consisting of tungsten, molybdenum, tungsten-rhenium and molybdenum-rhenium;

c. an emissive material constituted by a semiconductive material having a low work function impregnating the pores of said layer; and

d. means to pass electrical current through said substrate to heat the cathode structure to its operating temperature.

2. A cathode as set forth in claim **1**, wherein said substrate is a tungsten-rhenium alloy, the percentage of rhenium being about 3 percent by weight.

3. A cathode as set forth in claim **1**, wherein said substrate is formed mainly of molybdenum.

4. A cathode as set forth in claim **1** wherein said emissive material is $BaO:CaO:Al_2O_3$, having a 4:1:1 mole ratio.

5. A cathode as set forth in claim **1**, wherein said porous layer has a thickness of at least .001 inch.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,558,966 Dated January 26,1971

Inventor(s) David L. Hill and Lien S. Wu

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 1 should read as follows:

1. A directly heated dispenser cathode structure comp ing:
a. a solid substrate of electrically conductive material, s substrate being formed of tungsten wire capable of being coiled;
b. a layer of porous material bonded to said substrate and formed of refractory metal , said layer material being selected from a class consisting of tungsten, molybdenum, tungsten-rhenium and molybdenum-rhenium;
c. an emissive material constituted by a semiconductive material having a low work function impregnating the pores of said layer; and
d. means to pass electrical current through said substrate heat the cathode structure to a temperature at which an act metal is produced which passes through the pores of said la to the emitting surface thereof to continuously replenish the active metal which has been evaporated or sputtered fro the surface.

Signed and sealed this 25th day of May 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents