

Aug. 6, 1957

D. DOBISCHEK ET AL

2,802,127

DYNODE COATING

Filed Feb. 3, 1954

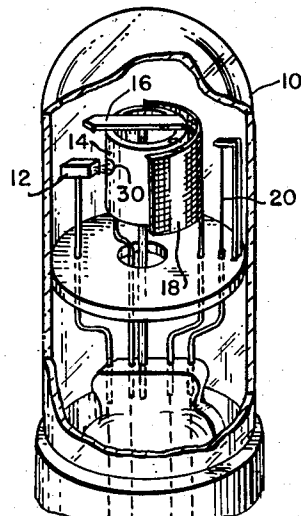


FIG. 1

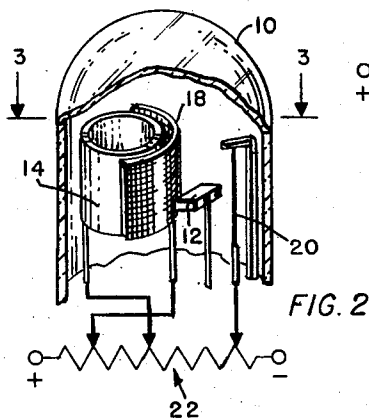


FIG. 2

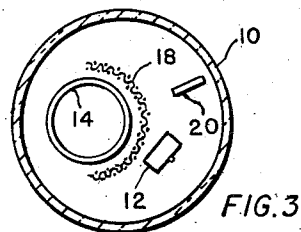


FIG. 3

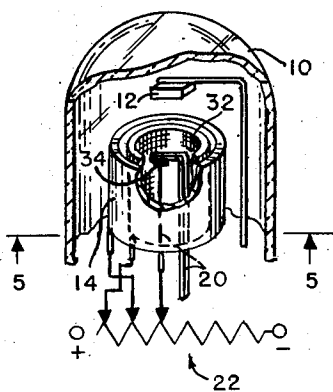


FIG. 4

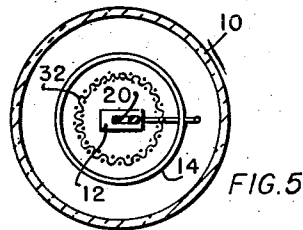


FIG. 5

INVENTORS

DIETRICH DOBISCHEK

BY JOHN B. FREELY

HAROLD JACOBS

Harry M. Saragovitz
ATTORNEY

1

2,802,127

DYNODE COATING

Dietrich Dobischek, Asbury Park, John B. Freely, Red Bank, and Harold Jacobs, West Long Branch, N. J., assignors to the United States of America as represented by the Secretary of the Army

Application February 3, 1954, Serial No. 408,053

11 Claims. (Cl. 313-103)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

The present invention relates to discharge devices. More particularly, it relates to electrode coatings adapted for use therein and to method for preparing the same.

There have already been many efforts to improve the emission characteristics of oxide coatings on emissive cathodes and on target electrodes which provide secondary emission. As a result of research carried out by the inventors, it was first learned that if high D. C. fields are applied across certain oxide films, unusually high secondary emission ratios are produced, the applied high D. C. field causing an enhancement of the secondary emission ratio. This enhanced emission may become self-sustained if a high enough D. C. is applied across the film.

It is, accordingly, a primary object of the present invention to provide a method of preparing a coating on an electrode in a discharge device which is stable, reproducible, and capable of providing high, self-sustained secondary emission.

It is a further object to provide a discharge device wherein such a coating is adapted for use such as a noise-generator.

It is another object to provide a device wherein such a coating is adapted for use in a display tube.

In accordance with the present invention there is provided a method of preparing a magnesium oxide coating for an electrode in a discharge device, the coating being characterized by enhanced secondary emission when bombarded with electrons, comprising filling with oxygen at a pressure of 20-40 mm. of mercury, an envelope having therein a metal receptacle containing magnesium and an electrode spaced from said receptacle, initiating the positive ionization of said oxygen, positively biasing said electrode with respect to said receptacle whereby a glow discharge is set up therebetween, the positive ions being attracted to said receptacle thereby igniting said magnesium, permitting said ignited magnesium to burn in said oxygen for a predetermined period whereby a thin, stalactite like, porous magnesium oxide coating is deposited on said electrode.

Also in accordance with the present invention there is provided a discharge device comprising an evacuated envelope including therewithin at least an emitting cathode and an anode having a stalactite like porous magnesium coating thereon, said coating having a high secondary to primary emission ratio.

For a better understanding of the invention together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a perspective view partially cut away, of a discharge device in accordance with a preferred embodiment of the present invention; Fig. 2 is a perspective view of a second embodiment; Fig. 3 is a

2

section taken along line 3-3 of Fig. 2 looking in the direction of the arrows; Fig. 4 is a perspective view of a third embodiment of the present invention and Fig. 5 is a section taken along line 5-5 of Fig. 4 looking in the direction of the arrows.

Referring more particularly to Fig. 1 there is shown a device for providing the magnesium oxide coating of the present invention. An evacuable tube 10 or chamber which is provided with means (not shown) for introducing oxygen or other gas therein and with means (not shown), for exhausting gas therefrom has positioned therewithin an assembly comprising a metal receptacle 12 containing metal magnesium foil. Opposing and spaced from receptacle 12 a predetermined distance is a first portion of the surface of a rotatable cylindrical dynode 14. For rotatably positioning dynode 14 there is provided a tab 16 responsive to a magnetic field (not shown) external to tube 10. Spaced from the dynode is an accurately contoured grid structure 18 concentric to a second portion of the surface of the dynode. Opposing and spaced from grid structure 18 is a cathode 20 which may be a filament or a cathode of the indirectly heated type and whose emitting surface is in the same horizontal plane as receptacle 12. A D. C. potential source 22 provides the necessary electrode biasing potentials in the fabrication of the tube as will be hereinafter explained. All the structural elements inside chamber 10 are supported by devices well known in the art and it is, therefore, believed unnecessary for them to be set forth.

In operation, tube 10 is filled with oxygen to a pressure of 20-40 mm. of mercury. The ionization of the oxygen is initiated by a spark from a spark coil, by light, or other suitable means. Dynode 14 is then made several hundred volts more positive than magnesium receptacle 12 so that a glow discharge is initiated therebetween. A current limiting resistor may be connected in the dynode receptacle circuit to prevent excess current from being drawn. The glow discharge results in a positive ion bombardment which causes the magnesium receptacle 12 to heat very rapidly, thereby igniting the magnesium therein. The magnesium burns violently and deposits as a fine, white stalactite like layer magnesium oxide layer 30 on a spot on dynode 14. After the magnesium oxide layer 30 is so formed, the applied positive potential is disconnected from dynode 14, and the dynode is induction heated at about 700°-800° C. in the oxygen for about 30 seconds to complete the oxidation. After the latter oxidation step, the oxygen is pumped out. Dynode 14 is made positive with respect to cathode 20 and is rotated by application of an external magnetic field to tab 16 so that the formed spot area of magnesium oxide coating 30 is directly opposite cathode 20, grid structure 18 being intermediate coating 30 and cathode 20. Cathode 20 is energized by a suitable (not shown) potential source so that electrons are emitted therefrom and, inasmuch as dynode 14 is positive with respect to cathode 20, the electrons bombard magnesium oxide coating 30 setting up a secondary emission of several milliamperes. At this point, the grid structure is made positive with respect to the cathode, the secondary emission becomes self sustained and the magnesium oxide coating emits electrons even when the primary electron source, the cathode is cut off. The self sustained emission is drawn from the coating to the grid structure for several minutes to remove any gas that may have been occluded in the oxide coating. Finally, the getter (not shown) is flashed and the tube is sealed at a pressure of about 10⁻⁷ mm. of mercury, all the potentials are removed from the various electrodes of the tube, and the tube is now ready for operation.

The magnesium oxide film as produced above provides extremely large secondary emission ratios when bom-

barded with electrons. It is to be noted that the magnesium oxide deposit has to be quite porous to obtain such high currents and this porosity is obtained by the evaporation of magnesium through oxygen. Contrariwise, a smooth deposit results when the evaporation is first carried out in a vacuum rather than through oxygen and then oxidizing the evaporated surface. When examined microscopically, the surface formed by evaporation through oxygen consists of a uniform distribution of small stalactite structures approximately 6×10^{-7} cm. long and 2×10^{-4} cm. wide. In the case of the deposit carried out in vacuum, the shape of the grains after oxidation is generally more spherical and not of uniform size.

The high oxygen pressure used (20–40 mm. of mercury) prevents the magnesium from evaporating at low temperatures. The positive ion bombardment heats the magnesium sufficiently so that it becomes ignited and burns off forming magnesium oxide fumes which deposit as a spot of thin white film on the dynode. It is necessary to have an oxygen pressure in the range of 20–40 mm. of mercury as evaporation of the magnesium in lower pressures of oxygen results in both a very poor positive ion production at the initiation of the process and a low concentration of oxygen in magnesium oxide formation. This, in turn requires heating of the magnesium indirectly by a filament and evaporation of the magnesium at low temperatures and also results in incomplete oxidation. Consequently, where lower than critical pressures of oxygen are maintained, the magnesium oxide formed on the anode has to be further oxidized by R. F. heating and even when the latter step is done, the magnesium oxide film is not completely oxidized. The layers that are obtained from the oxygen pressure, accordingly, are also somewhat unstable and difficult to reproduce. In the method of the present invention, the oxidation of the magnesium is complete due to high pressure of oxygen utilized and the consequent higher temperatures and initial positive ion production. Therefore, the magnesium oxide layers are more exactly reproducible.

In understanding the mechanism of secondary emission from thin dielectric films such as magnesium oxide, it is to be realized that high D. C. fields are applied across these films while the film is being bombarded with primary electrons. The secondary emission ratio is found to increase exponentially with the field over a wide range of bombardment energy. It is believed that primary electrons bombard the uncharged magnesium oxide film thus liberating electrons by ordinary secondary emission with a ratio greater than unity. As a result of its high resistivity, the secondary emission surface acquires a large positive charge, and a high field is created across the film. Due to the porosity of the film, subsequent bombarding electrons will penetrate a fixed distance into the magnesium oxide. Secondary electrons released within the material are accelerated towards the surface of the film under the influence of this high field. The secondary electrons travel largely through the pores, gaining sufficient energy from the field to create further electrons by impact. Each new secondary electron creates additional electrons by internal ionization, and a Townsend type avalanche results. As, hereinbefore described, the emission becomes self sustained and the limit of gain is finally reached when the surface of the magnesium oxide film approaches that of the collector grid, viz; the grid structure 18. If the surface potential becomes higher than that of the collector grid, the electrons return to surface, neutralizing some of the positive charges. If the surface falls below the grid potential, the emission of electrons will quickly charge the surface more positively and an equilibrium potential will be established. The surface of the film thus becomes a uni-potential region of positive charges, similar to the condition existing in the cathode glow region of a gaseous glow discharge.

As set forth above, the magnesium oxide layers produced by the method of the present invention provides self sustained emission up to 50 ma. which are stable and substantially reproducible. It is believed that the electron avalanche in the oxide is probably due to the fact that the oxide layers under microscopic examination are made up of stalactite like structures and are porous. The porous layers provide long electronic mean free paths, permitting the electrons to gain sufficient energy from the field between collisions to cause further ionization in the oxide, resulting in an electron avalanche.

Inasmuch as the porous magnesium oxide layer produces such extremely high secondary emission currents, it has been found that these secondary electrons have high initial velocities and may be utilized to provide vacuum tubes which can effectively be used as a noise generator.

The tube of Fig. 1 may be used as such a generator. In such a tube, the self sustained emission of magnesium oxide coating 30 on dynode 14 has run self sustained in excess of 500 hours. By the use of rotatable dynode 14, the cleanness of grid structure 18 is assured in the fabrication of the tube. Of course, dynode 14 could be a fixed structure and grid structure 18 movable and in this manner also insure prevention of contamination on the grid.

In Figs. 2 and 3, there is shown a miniature tube noise generator wherein the present magnesium oxide coating is utilized. In this embodiment, the magnesium oxide is deposited in the manner as described in the tube of Fig. 1 from the magnesium receptacle 12 through grid structure 18 onto dynode 14. In this situation, grid structure 18 also becomes coated with magnesium oxide so that it is possible to obtain large, random, self sustained emission currents from grid structure 18 to dynode 14 by bombarding the grid with primary electrons and making dynode 14 positive with respect to the grid structure a suitable value being about 100 volts. In any event, using either dynode 14 or grid 18 as the secondary emitter, it is possible to obtain self sustained emission up to about 50 ma.

In Figs. 4 and 5 there is shown, a subminiature tube noise generator utilizing the coating of the present invention. In this embodiment a cylindrical grid structure 32 is positioned concentrically within and spaced from cylindrical dynode 14. Filament 20 is positioned within grid structure 32 and magnesium receptacle 12 containing magnesium filings is situated above the dynode 12, grid 32 and filament 20 substantially along the axis of dynode 14. In the fabrication of this embodiment, the glow discharge is initiated between receptacle 12 and dynode 14 and grid 32 resulting in a magnesium oxide coating on the grid and the inner surface of dynode 14. To prevent any magnesium oxide from depositing on the filament, a disc 34 of nickel or the like metal is spot welded or affixed in a suitable manner to the top of filament 20. As an added precaution, to prevent contamination of the layer by getter (not shown) metal such as barium when the getter is flashed, a mica shield (not shown) may be inserted between the getter and tube elements thereby shielding the magnesium oxide layer.

In the operation of these noise generator tubes, the dynode and grid are placed at the same potential, about 100 volts more positive than the filament, and the oxide layer is bombarded by primary electrons from the filament. The grid potential is then raised and the secondary current from the oxide begins to exhibit a blue fluorescence which becomes more intense as the current increases. In effect, such a tube may be utilized to provide a visible display. At a secondary current of several hundred microamperes, the emission becomes self sustained. The self sustained current may then be varied by changing the grid potential and will show exponential dependence upon the difference of potential between the 75 dynode and the grid.

While there have been described what at present are considered to be preferred embodiments of the invention, it will be understood by those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is therefore aimed in the appended claims to cover all such modifications as fall within the spirit and scope of the invention.

What is claimed is:

1. A method of preparing a magnesium oxide coating for an electrode in a discharge device, said coating being characterized by greatly enhanced secondary emission when bombarded with electrons comprising filling with oxygen at a pressure of 20-40 mm. of mercury, an envelope having therein a metal receptacle containing magnesium and an electrode spaced from said receptacle, initiating the positive ionization of said oxygen, positively biasing said electrode with respect to said receptacle whereby a glow discharge is set up therebetween, said positive ions being attracted to said receptacle thereby igniting said magnesium, permitting said ignited magnesium to burn in said oxygen until said magnesium is completely oxidized whereby a thin, porous, stalactite like coating of magnesium oxide is deposited on said electrode.

2. A method of fabricating a discharge device comprising an envelope containing therewithin at least a cathode, an anode having a porous stalactite like magnesium oxide coating thereon, and a metal receptacle containing magnesium comprising introducing oxygen into said envelope at a pressure of 20-40 mm. of mercury, initiating the positive ionization of said oxygen, providing a glow discharge between said metal receptacle and said anode by biasing said anode positive with respect to said receptacle whereby said positive oxygen ions are attracted to said receptacle igniting said magnesium, permitting said magnesium to burn in said oxygen until said magnesium is completely oxidized whereby a porous stalactite like magnesium oxide coating forms on said anode.

3. A method as in claim 2 wherein said anode is made from 400 to 600 volts positive with respect to said receptacle.

4. A method of fabricating a discharge device comprising an envelope containing therewithin a cylindrical rotatable anode having a porous stalactite like magnesium oxide coating thereon, an emitting cathode spaced from a first portion of the cylindrical surface of said anode, an open mesh grid structure intermediate said cathode and said anode and a metal receptacle containing magnesium spaced from a second portion of the cylindrical surface of said anode comprising introducing oxygen at a pressure of 20-40 mm. of mercury into said envelope, initiating the ionization of said oxygen, providing a glow discharge by positively biasing said anode with respect to said receptacle whereby said oxygen ions are attracted to said receptacle and ignite said magnesium, permitting said magnesium to burn in said oxygen until said magnesium is completely oxidized whereby a porous stalactite like coating of magnesium oxide forms on said anode, exhausting said oxygen from said envelope.

5. A method as in claim 4 wherein said anode is biased from 400-600 volts positive with respect to said metal receptacle.

6. A method of fabricating a discharge device which provides self sustained secondary emission comprising an envelope containing therewithin an anode, having a porous stalactite like magnesium oxide coating thereon, an emitting cathode opposite a first portion of the anode surface, a metal receptacle opposite a second portion of the said anode surface and a grid intermediate said cathode and receptacle and said anode comprising introducing oxygen at a pressure of from 20-40 mm. of mercury into

said envelope, initiating the positive ionization of said oxygen, providing a glow discharge between said anode and grid and said receptacle by biasing said anode and grid from 400-600 volts positive with respect to said receptacle whereby said oxygen ions are attracted to said receptacle and ignite said magnesium, permitting said magnesium to burn in said oxygen until said magnesium is completely oxidized whereby said porous stalactite like magnesium oxide coating forms on said grid and said anode.

7. A method of preparing a discharge device comprising an envelope containing therewithin a substantially cylindrical anode having a porous stalactite like secondary electron emitting magnesium oxide coating thereon, a substantially cylindrical grid concentrically positioned within and spaced from said anode, an emitting cathode positioned within said grid, and a metal receptacle containing magnesium positioned at point outside of and substantially along the axes of said cylinders comprising introducing oxygen at a pressure of from 20-40 mm. of mercury into said envelope, initiating the positive ionization of said oxygen, providing a glow discharge between said anode and grid and said receptacle by biasing said anode and grid positive with respect to said receptacle whereby said oxygen ions are attracted to said receptacle and ignite said magnesium, permitting said magnesium to burn in said oxygen until said magnesium is completely oxidized whereby a porous stalactite magnesium oxide coating forms on said grid and said anode.

8. A discharge device comprising an evacuated envelope including therewithin at least an emitting cathode and an anode having a porous magnesium oxide coating thereon, said coating consisting of magnesium oxide crystals of stalactite like structure and having a high secondary to primary emission ratio.

9. A discharge device characterized by high self sustained secondary emission comprising an evacuated envelope including therewithin an emitting cathode, an anode having a porous magnesium oxide coating thereon, said coating consisting of magnesium oxide crystals of stalactite like structure, and a grid intermediate said anode and cathode.

10. A noise generator comprising an evacuated envelope including therewithin a primary electron emitting cathode, an anode having a secondary electron emitting porous magnesium oxide coating thereon, said coating consisting of magnesium oxide crystals of stalactite like structure and having a high secondary to primary emission ratio, a grid intermediate said anode and cathode, means for energizing said cathode, means for biasing said anode positive with respect to said cathode whereby a portion of said secondary electron emission from said anode is available for noise.

11. A visible display tube comprising an evacuated envelope including therewithin at least a primary electron emitting cathode, an anode having a secondary electron emitting porous magnesium oxide coating thereon, said coating consisting of magnesium oxide crystals of stalactite like structure and having a high secondary to primary electron emission ratio, the secondary electron current from said coating providing a fluorescent display.

References Cited in the file of this patent

UNITED STATES PATENTS

1,802,474	Lebrun et al.	Apr. 28, 1931
2,146,607	Van Overbeek	Feb. 7, 1939
2,151,783	Lopp et al.	Mar. 28, 1939
2,171,227	Schreinemachers	Aug. 29, 1939
2,198,329	Bruining et al.	Apr. 23, 1940
2,401,040	Becker	May 28, 1946
2,526,574	Mendenhall	Oct. 17, 1950