

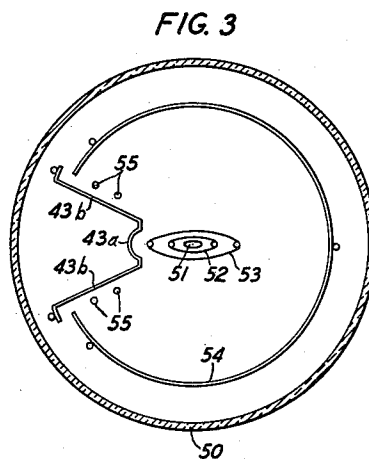
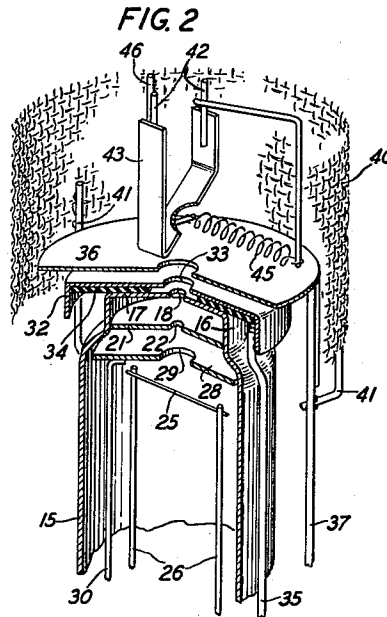
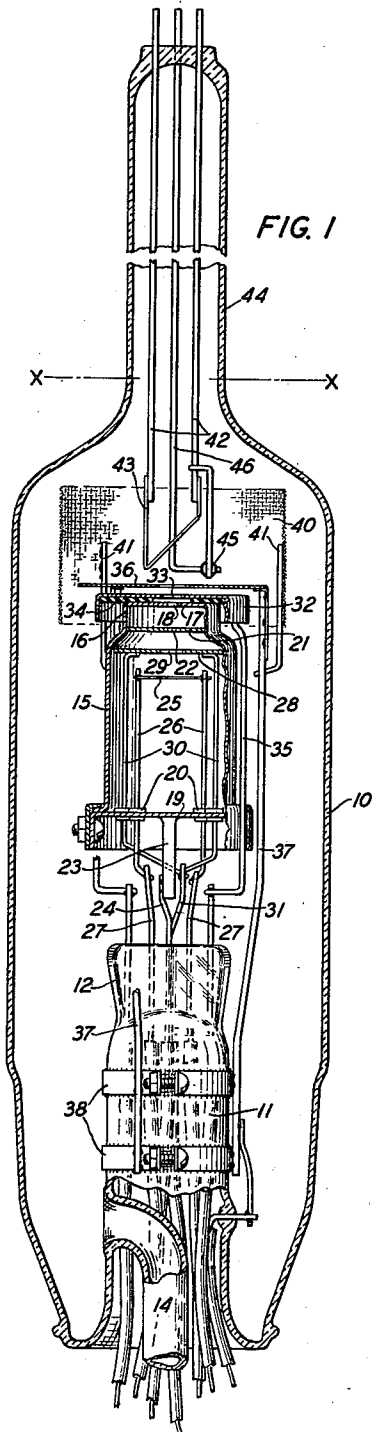
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SECONDARY ELECTRON EMISSIVE ELECTRODE

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SECONDARY ELECTRON EMISSIVE
ELECTRODE

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This invention relates to electron discharge devices and more particularly to such devices comprising one or more secondary electron emissive electrodes and to methods of making such electrodes.

The operating characteristics and useful life of electron discharge devices including one or more secondary electron emissive electrodes are dependent primarily upon the character and properties of the emissive surface of such electrodes. In general, such surfaces include alkaline or alkaline earth metals in either the free or combined form or both. It has been found that known surfaces are unstable, that the emission characteristics thereof vary with use of the device and that in a relatively short period the quantity of emission obtainable becomes insufficient for satisfactory and proper operation of the device.

These undesirable effects are attributable to changes in the character and composition of the emissive surfaces. For example, it has been found that in devices wherein the secondary emissive surface includes alkaline or alkaline earth metal in the form of an oxide, the oxide exists in the form of a relatively thin layer upon a sub-layer of free metal. During operation of such a device, some of the free metal diffuses through the oxide layer and appears upon the emissive surface. Inasmuch as, in general, the free or uncombined metal has a lower secondary electron emission factor than the oxide thereof, in devices of the type described, the diffusion of the free metal to the emissive surface results in a marked decrease in the total emission obtainable from the surface.

In other cases wherein the secondary electron emissive element is in the form of a matrix including some free active metal, such for example as in the known caesium silver oxide coatings on electrodes, the emission characteristics of the element deteriorate materially in the presence of even small amounts of oxygen. If, in devices including such elements, oxygen is liberated from the internal parts during operation, the emissive element is affected deleteriously.

Furthermore, the preparation of secondary electron emissive surfaces heretofore involved manifold difficulties and entailed an exacting procedure due, for example, to the necessity of keeping the surface, once activated, in a high vacuum and to the critical dependence of the characteristics of the surface ultimately produced upon the proportions of the constituent

materials of the surface and upon the temperatures employed during the formation process.

General objects of this invention are to improve the operating characteristics and to increase the useful life of electron discharge devices comprising one or more secondary electron emissive electrodes.

More specifically, objects of this invention are to:

10 Improve the stability and emission characteristics of secondary electron emissive surfaces;

Increase the operating life of secondary electron emissive surfaces;

15 Facilitate control of the quantity of active ingredient in such surfaces; and

Simplify and expedite the production or fabrication of secondary electron emissive electrodes.

In accordance with one feature of this invention, a secondary electron emissive electrode comprises a metallic base having thereon a coating of a secondary electron emissive metallic oxide having a secondary electron emission factor of greater than unity, the coating having substantially no free active metal therein. The coating may be, for example, of magnesium oxide, aluminum oxide or beryllium oxide.

In accordance with another feature of this invention, a foundation member of relatively inactive metal is treated to produce thereon a coating of a definite amount of oxide of the metal, a layer of active metal is applied to the oxide coating, the composite thus formed is heated whereby the active metal reduces the oxide coating, and the assembly is heated further to vaporize the remaining free active metal.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

40 Fig. 1 is a view mainly in section illustrating one form of apparatus which may be employed in producing and testing secondary electron emissive electrodes in accordance with this invention;

45 Fig. 2 is an enlarged detail view in perspective of a portion of the apparatus shown in Fig. 1; and

Fig. 3 is a view in cross-section of an electron discharge device including a secondary electron emissive electrode constructed in accordance with this invention.

Referring now to the drawing, the apparatus illustrated in Figs. 1 and 2 comprises an enclosing vessel 10 having at one end a stem 11 which terminates in a press 12 and from which an electrode system is supported. The vessel 10 is pro-

vided at one end with a tubulation 14 for purposes to be described hereinafter.

The electrode system comprises a cylindrical metallic shield 15 having a reduced end portion 16 which is closed by a disc 17 having a restricted central aperture 18 therein. Affixed to the other end of the shield 15 is a cup-shaped cap or closure 19 provided with a plurality of apertures in which insulating bushings 20 are secured. Fixed within the reduced end portion 16 is a disc or diaphragm 21 having a central aperture 22 in alignment with the aperture 18. The shield 15 may be supported in part by a rigid upright 23 affixed to a rigid wire 24 embedded in the press 12 and having a leading-in conductor connected thereto.

Mounted within the shield 15 is a cathode 25, for example a tungsten filament, which is supported in alignment with the apertures 18 and 22 by a pair of uprights 26 extending through bushings 20 and carried by wires 27 sealed in the arms of the press 12 and having leading-in conductors connected thereto.

Also mounted within the shield 15 and located between the cathode 25 and diaphragm or disc 21 is a modulator disc 28 having a central aperture 29 in alignment with the apertures 18 and 22. The modulator disc 28 may be supported by a pair of rigid uprights 30 extending through bushings 20 and carried by a rigid wire 31 embedded in the press 12 and having a leading-in conductor connected thereto.

An inverted cup-shaped electrode 32 having a central aperture 33 in alignment with the aperture 18 is seated upon a centrally apertured insulating disc 34 seated in turn upon the closure member 17. The electrode 32 may be supported further by a plurality of uprights 35 embedded in the press 12, one of the uprights having a leading-in conductor connected thereto.

A centrally apertured disc collector electrode 36 is mounted above and in alignment with the electrode 32 and may be supported by a plurality of metallic uprights 37 carried by a pair of collars or bands 38 clamped about the stem 11, one of the uprights 37 having a leading-in conductor connected thereto as shown. The uprights 37 support also a cylindrical mesh screen or shield 40 which is mounted on rigid wires 41 secured to the uprights 37.

Mounted opposite the collector electrode 36 and in alignment with the aperture therein is a target 43 which may be supported by a pair of leading-in conductors 42 sealed in the outer end of a tubulation 44 on the vessel 10. This target, which may be a strip of metal, serves as the foundation member for the secondary electron emissive surface produced as described hereinafter.

An auxiliary filament 45, for example, a helix of tungsten, is positioned opposite the base wall of the target 43 and is supported by a leading-in conductor 46 and one of the conductors 42 as shown. A strip or pellet of vaporizable material, not shown, is mounted on or within the helical filament for purposes to be described hereinafter.

The target electrode 43 constitutes the base or foundation member of the secondary electron emissive electrode to be produced. In a specific form, it may be a strip of substantially pure silver or of a base metal plated with silver. In the fabrication of the secondary electron emissive electrode, the various electrodes in the vessel 10 are outgassed and the vessel is evacuated through

the tubulation 14. To assist in outgassing the target 43 a current may be passed therethrough by way of the conductors 42. Pure oxygen is then admitted, through the tubulation 14, into the vessel 10, for example to a pressure of the order of 0.2 to 0.8 millimeter of mercury, and a glow discharge is produced between the target electrode 43 and another electrode, preferably the collector electrode 36, as by applying a potential of the order of 1000 volts between these two electrodes, whereby a coating of silver oxide is produced upon the electrode 43. The vessel 10 thereupon is evacuated to a high degree.

A current is then passed through the filament 45 to vaporize the strip or pellet, for example of magnesium, thereon. The vaporized material deposits upon the oxidized target electrode and forms a layer of magnesium thereon. The target electrode is heated, as by passing a current therethrough by way of the conductors 42, whereby the silver oxide is reduced by the magnesium and a layer of magnesium oxide is formed on the target electrode. The composite element thus produced is heated still further, as by passing a current therethrough, to a degree sufficient to reduce substantially all of the silver oxide and to vaporize any free magnesium in the coating produced, whereby the final coating substantially consists of magnesium oxide. Heating to about 700° C. has been found satisfactory to reduce the silver oxide and to vaporize any free magnesium that may remain after such reduction. The target electrode may then be removed from the vessel 10, as by cutting the vessel along the plane x—x, and mounted in the device wherein it will be used as a secondary electron emissive electrode.

Magnesium oxide has a high secondary electron emission factor. Magnesium itself, on the other hand, has a low secondary emission factor. It will be noted that secondary electron emitters produced as described above will have uniform emission characteristics over a long period inasmuch as, because of the decrease or substantial absence of free magnesium, no magnesium spots will be produced upon the emissive surface.

It will be noted further that the process described above is readily controllable. That is to say, the silver can be oxidized to produce a known amount of silver oxide. The quantity of magnesium necessary to reduce the silver oxide coating and produce a coating of a known quantity of magnesium oxide is easily determinable, so that the fabrication of secondary electron emissive electrodes is greatly facilitated.

Although in the specific illustration described above, a magnesium oxide coating is produced upon a silver base, it will be understood that other oxide coatings may be produced and other base or foundation materials may be employed. For example, coatings of aluminum oxide, barium oxide and beryllium oxide, each of which has good secondary emission properties, may be produced in the manner described above. The base or foundation metal employed in any particular case should be such that the oxidizing agent has a suitable equilibrium pressure. That is to say, the oxidizing agent should be such that it is reduced by the active metal at a temperature below that at which the active element evaporates appreciably from the composite element. In the specific illustration described, the oxidizing agent, silver oxide, is reduced by magnesium at a temperature materially below the vaporizing temperature of magnesium. Gold oxide also may be

employed as a base on which magnesium is deposited. Silver oxide also may be used as the oxidizing agent for aluminum to produce a secondary electron emissive surface of aluminum oxide. Cupric oxide or nickel oxides may be used as the oxidizing agent for beryllium or barium.

Although oxides have been described specifically as the oxidizing material, other compounds may be utilized. In general, the requisites for such compound are that it be capable of giving up oxygen at the proper temperature and that the residue be stable at the operating temperature of the emitting surface produce. An illustrative compound which may be used is copper chromate.

When any secondary electron emitting electrode has been constructed as described above, the emission factor of the oxide coating may be determined readily in the apparatus shown in Fig. 1. For this purpose, the electrodes 15, 25, 28 and 21 are operated as an electron gun to produce a concentrated beam of electrons emanating from the cathode 25, which is accelerated by electrodes 21, 17 and 32, passes through the aperture 33 and impinges upon the target electrode 43 to cause the emission of secondary electrons from the target electrode. These secondary electrons will be collected by the collector electrode 36 and shield 40, which, as noted heretofore, are electrically connected together. The magnitude of the difference between primary electron current impinging upon the target and secondary current therefrom can be measured directly as by a meter in the target circuit. The secondary current flowing between the target electrode 43 and the collector electrode 36 and shield 40 can be measured directly. The ratio of secondary electron current to primary electron current is a measure of the emission factor of the secondary electron emissive surface produced.

An electron discharge device illustrative of those in which secondary electron emissive electrodes constructed in accordance with this invention may be employed is shown in Fig. 3. This device comprises an enclosing vessel 50 in which there are mounted in coaxial relation a cathode 51, an oval or elliptical control grid 52, an oval or elliptical screen grid 53 and a generally cylindrical focussing electrode 54 having a cut-away portion in which the target electrode is positioned. The target electrode may include a central semicircular portion 43a and wings 43b. Opposite the wings 43b of the target electrode are a plurality of parallel linear elements 55, for example wires, which are connected together electrically and constitute an auxiliary electrode or anode. The cathode 51 may be of either the filamentary or indirectly heated type and have its surface coated with a material having good electron emission properties. For example, the surface may have thereon a coating including barium oxide.

During operation of the device, the focussing electrode 54 is connected directly to the cathode 51 or has a small potential applied thereto, the grid 53 and target electrode 43 are connected together and maintained at a positive potential with respect to the cathode 51 and the auxiliary electrode 55 is maintained at a high positive potential with respect to the cathode. A suitable load or utilization circuit may be connected between the electrode 55 and the cathode 51 to obtain a positive transconductance or between the

target electrode 43 and the cathode 51 to obtain negative transconductance.

The primary electrons emanating from the cathode 51 will be directed to the target electrode and impinge upon the wings 43b whereby a secondary electron current to the auxiliary electrode 55 is produced. The current supplied to the load or utilization circuit, connected between the target electrode 43 and cathode 51, will be the difference between the primary electron current to the target electrode and the secondary electron current from the target electrode. When the secondary electron current from the target electrode is greater than the primary electron current to it, a negative transconductance is realized inasmuch as the net electron flow is away from the target electrode and, hence, opposite in direction to that in positive transconductance devices.

It will be noted that inasmuch as free active metal is not present in secondary electron emissive surfaces constructed as described above, the construction of devices including secondary electron emissive electrodes is greatly facilitated. Electrodes constructed as described above can be exposed in air without any detrimental effects and no particular precautions are necessary, therefore, in handling such electrodes and in mounting them in devices wherein they are to be used.

Although a specific embodiment of this invention has been shown and described, it will be understood that this embodiment is but illustrative. For example, although the process of fabricating secondary electron emissive electrodes has been described with reference to particular apparatus wherein but one electrode is produced, such electrodes could be produced in quantity in an evaporating chamber, the necessary heating being accomplished by high frequency induction or in other ways. Also, although in the specific methods described the oxide or other compound of inactive metal is produced by treatment of the foundation member, such oxide or compound could be applied to a foundation member as, for example, by spraying. Various other modifications may be made in the specific embodiment described without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. The method of manufacturing a secondary electron emissive electrode, which comprises producing on a foundation member a coating of a compound of a relatively inactive metal which compound will liberate oxygen when heated and have a residue stable at the normal operating temperature of said electrode, depositing upon said coating a layer of an active metal an oxide of which has a secondary electron emission factor greater than unity, reducing said compound by heating the composite thus formed with said active metal whereby a layer of the oxide of said active metal is produced on said member, and removing substantially all free active metal from the assembly thus formed.

2. The method of manufacturing a secondary electron emissive electrode, which comprises producing on one surface of a foundation member of a relatively inactive metal a coating of an oxide of said metal, depositing upon the oxide coating a layer of an active metal the oxide of which has a secondary electron emission factor greater than unity, reducing said oxide coating by heating the composite thus formed with said

active metal whereby a layer of the oxide of said active metal is formed on said member, and removing substantially all free active metal from the assembly thus formed.

3. The method of manufacturing a secondary electron emissive electrode including a foundation member and a surface on said electrode of an active metal oxide having a secondary electron emission factor greater than unity, said method comprising oxidizing a surface of a foundation member of a metal the oxide of which is reducible by the active metal at a temperature below the vaporizing temperature of the active metal, depositing a layer of the active metal upon the oxidized surface, reducing substantially all the oxide of said foundation metal in said surface by heating the assembly thus formed with said active metal layer whereby a coating of the oxide of said active metal is produced on said foundation member, and vaporizing substantially all free active metal therein from said active metal oxide coating by heating the composite thus formed.

4. The method of manufacturing a magnesium

oxide secondary electron emitter which comprises oxidizing a surface of a foundation member of a metal the oxide of which is reducible by magnesium at a temperature below the vaporizing temperature of magnesium, depositing magnesium upon the oxidized surface, heating the composite element thus formed to reduce the oxide of said metal by the magnesium whereby a coating predominantly of magnesium oxide is produced on the foundation member, and heating the composite element further to vaporize any free magnesium therein.

5. The method of manufacturing a magnesium oxide secondary electron emitter which comprises oxidizing a surface of a foundation member of silver, depositing a layer of magnesium on the oxidized surface, and heating the assembly thus formed to approximately 700° C. whereby a coating of magnesium oxide substantially free of free magnesium is produced on said foundation member.

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