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SECONDARY EMITTER

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FIG. 1

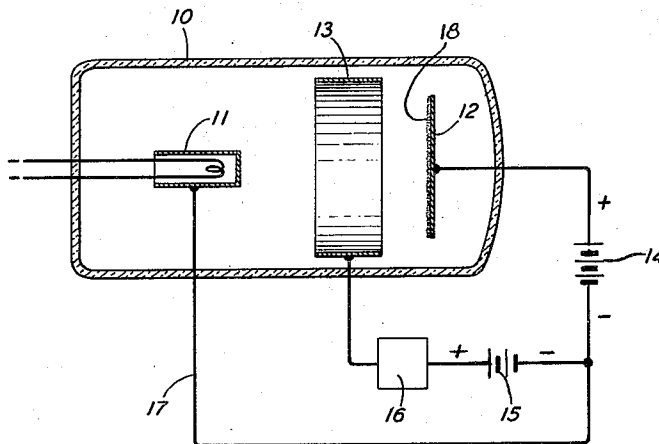
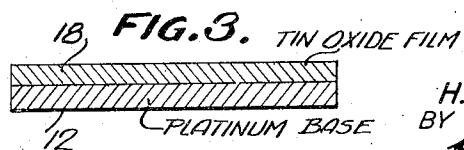
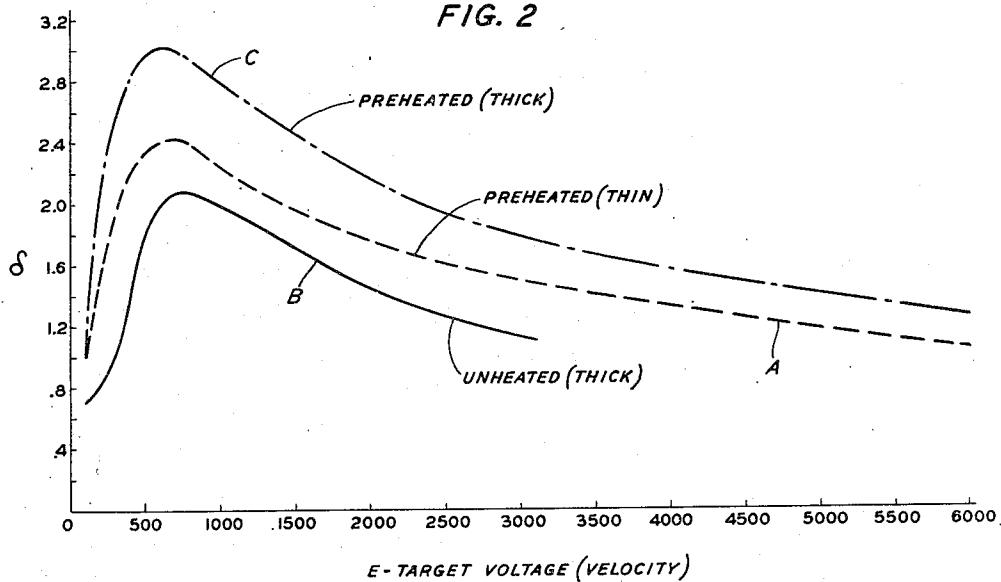


FIG. 2



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UNITED STATES PATENT OFFICE

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SECONDARY EMITTER

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10 Claims. (Cl. 250-174)

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This invention relates to secondary electron emitters or electrodes having high secondary electron emissivity which are useful in electronic discharge devices, such as electron multipliers, beam tubes and similar devices, and particularly to such emitters operating at high voltage levels.

Many emissive materials, alone or in combination, are well known as primary and secondary electron sources. Among such materials are alkali, alkaline earth and rare earth metals and their compounds, principally the oxides. Such materials, however, due to their low work function, have a relatively high decay character at normal operating voltages and therefore are unsuitable for high voltage operation, e. g., of the order of 3,000 to 10,000 volts.

An object of this invention is to increase the power output of devices operating on the secondary emission principle at high operating voltages and high primary energy densities.

Another object of the invention is to efficiently generate electron emission by impact in relatively thin films on metallic or insulating bases or foundations.

A further object of the invention is to attain high yields of secondary electrons in surface films of multiple interference rings thicknesses which will be stable at operating voltages of a high order.

These objects are attained by an emission source of secondary electrons energized by impact of primary electrons, produced on a foundation of metal or insulating material by applying a conductive layer or film of stannic or tin oxides thereon which yields a high ratio of secondary electrons at potentials of the order of 6,000 volts or less.

Such films have stable characteristics at high voltages, a substantially uniform emission at the higher voltages so that they do not exhibit the rapid decay of other types of emitters and, therefore, increase the efficiency and functional life of the devices for high voltage operation.

A feature of the invention relates to the development of surface films of the conductive oxides having high secondary emission on a base of a noble metal.

Another feature of the invention is concerned with the thermal effect of the films as a function of secondary electron emission output of the electrodes.

A further feature of the invention relates to the increase of emission at high voltages of conductive films of relatively thick layers having stable characteristics and high yield.

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These and other features are realized, in accordance with this invention, by the provision of a conductive oxide film of tin on a metallic surface, such as a platinum base, as a secondary emission source, or on an insulating base. When activated by impact of primary electrons, tin oxides have a high secondary emission yield which is especially significant at high operating voltages up to of the order of 6,000 volts and, therefore, may be utilized in multiplier devices of high power rating. The activity is stable over a wide range of voltages and does not materially decay when the thermal conditions of the films are varied by the increased potential differences between the input and output electrodes of the device during operation.

The secondary yield from thin films of the order of 500 to 30,000 angstroms thickness has a substantially linear characteristic over a range of voltages from 300 to 6,000 volts. Although the emission factor diminishes with increased voltages, the ratio is still greater than unity so that copious emission of true secondary electrons is produced at the high operating voltages.

The yield can be increased by thicker films operating under higher temperature conditions to supply a copious emission of secondaries for high power output. This is accomplished by applying successive films on the base to increase the thickness in multiples of the initial film to an extent of about nine interference rings thickness. The emission ratio is about 50 per cent higher than obtained from clean platinum and the films exhibit stability at relatively high voltages and high operating temperatures so that they do not decay rapidly over a long life. Appropriate heat treatments in which excess oxygen is removed increase the emission.

These features and other advantages of the invention will be set forth in detail in the following description and may be understood more clearly by reference to the accompanying drawing in which:

Figure 1 is a diagrammatic view of one embodiment of the invention as applied to an electron multiplier circuit in which the secondary emitter surface of this invention is involved;

Fig. 2 presents comparative graphic curves of secondary emission activity of different films illustrative of this invention; and

Fig. 3 a sectional view to an enlarged scale of the target electrode included in the device shown in Fig. 1.

Referring to the drawing, Fig. 1 shows an electronic multiplier circuit embodying this invention

and including a highly evacuated enclosing vessel 10, a source of primary electron emission therein in the form of a heater type cathode 11, although a filament type may be employed, axially directed toward a target electrode 12 mounted opposite the cathode and extending in a plane perpendicular to the axis of the cathode. A cylindrical collector or output electrode 13 is mounted coaxially with the cathode and target electrode and adjacent the periphery of the target electrode to receive secondary electrons emanating from the target. A potential source 14 is connected to the target electrode 12, the collector 13 being biased by a separate source 15 through a load or output device 16, and the common negative terminal of these sources is connected to the cathode through conductor 17.

The target electrode 12 is preferably a platinum disc provided with a thin film or coating of stannic or tin oxide 18 which is exposed to the primary electron emissive coating on the flat end of the cathode. Other noble metals, such as rhodium, iridium, palladium, etc. may be used instead of the platinum as the disc material. The multiplier device is primarily intended for high power operation wherein the voltage range is between 200 to 10,000 volts per stage for securing a large power output. Under such conditions, the target electrode emission must be extremely stable and not subject to rapid decay of the active coating, for supplying the secondary emission at high efficiency to establish a large output in the collector circuit, or in successive multiplier stages as set forth in the disclosure of United States Patent 2,298,960 issued October 13, 1942 to James W. McRae. If desired, multiple or plural targets may be provided in the same envelope. In a like manner the collector electrodes may be increased to correspond to the targets.

In accordance with this invention, the secondary emission coating is applied to the target electrode as a relatively thin film between 500 to 15,000 angstrom units thickness or equivalent, at the maximum range, to a thickness of less than three interference rings. Such thin films have been found to possess stable characteristics over a large voltage range, particularly at high voltages of the order of 1,000 to 6,000 volts when bombarded by primary electrons to produce true secondary electrons. The emission ratio or coefficient for thin films is greater than unity and the emission voltage characteristic is substantially a straight line over a large range of voltages and reaches a maximum emission ratio of 2.7 at about 600 volts. When the film is increased to six interference rings thickness the ratio reaches a maximum of 3.25 at 640 volts primary impact electrons when the film is preheated to 850° C. A further increase in thickness to nine interference rings produces an emission ratio of 2.6 maximum at 700 volts after the surface is preheated to 900° C. for several hours. The activated surface films have a long life at high voltage operation and are not subject to decay at elevated temperatures due to the high velocity electron impact.

The secondary emission surface may be prepared by the vapor diffusion process in a chamber evacuated to a low pressure of approximately 1×10^{-6} millimeters of mercury, in which the base metal, e. g., clean platinum, surface is exposed to the vapor of tin tetrachloride with the result of a tin compound film being deposited on the platinum surface, of thickness depending on

the time and temperature of deposition. The thickness of the film may be regulated by determining the amount of deposited material according to spectrometrical measurements in which reflected light indicates the number of interference rings present in the film as a measure of the thickness of the film. The tin coating on the base metal may have a thickness from 500 to 15,000 angstrom units, the maximum being equivalent to about three interference rings thickness. The tin film is oxidized by exposure to oxygen or heating in air to produce the stable emission surface or by depositing tin tetrachloride vapor in air against a target warmed to the order of 500° C.

When the thin film is bombarded by primary electrons of 600 volts velocity, if no prior heat treatment of the film is required, the secondary emission ratio from tin oxide has a value of $\delta=2.15$ or approximately a 50 per cent increase in emissivity over that of clean platinum. This value may be increased at the same impact voltage by preheating the film and target electrode from 700° C. to 960° C. for periods of 2 to 4 hours in vacuum. By preheating at 875° C. for 4 hours the emission ratio increases to 2.7. While the high ratio is prevalent at the specified voltages, the secondary electron emission is still higher than unity over a large voltage range up to 6,000 volts so that the conductive oxide thin film serves as an efficient secondary emission source which is not subject to decay at these higher voltages and, therefore, fills a role in attaining high power output in multiplier applications.

If larger ratios are desired for certain applications, the tin or stannic oxide film may be increased in thickness in multiples of the initial coating. For instance, a coating of six interference rings or 30,000 angstrom units, without preheat treatment, established an emission ratio at 640 volts impact velocity of 2.09 but when preheated at 750° C. for 2 hours similar results were obtained over a range from 100 to 3,000 volts and in one example where preheating of the thick film occurred for a period of 50 hours at 750° C. the emission curve was uniform up to 6,000 volts impact velocity. The film may be increased to nine interference rings or more with attendant increase in secondary emission value which will not decay at high primary electron impact levels up to 10,000 volts velocity.

The ability of the tin oxide active film to withstand rapid decay at high operating voltages and impact temperatures may be appreciated by reference to Fig. 2 which presents characteristic curves obtained from different film thicknesses and conditioning over a target voltage velocity range from 100 to 6,000 volts and the resultant secondary emission ratio or δ factor. Curve A represents a thin film of 15,000 angstrom units or three interference rings thickness, the curve being a mean value for different coatings from a film before heating to films preheated from 700° C. to 960° C. for 2 hours duration prior to sealing in the vessel in which it is mounted. The mean value shows an emission from unity at 100 volts to a value slightly above unity at 6,000 volts with a high above 2.4 at 640 volts. The mean characteristic was obtained with a thin film which was preheated for 2 hours duration at 850° C. The values for other heat treatment periods were slightly higher or lower over the same range.

Curve B represents a film of six interference rings or 30,000 angstrom units thickness, without

preheat treatment of the coating prior to impact. The secondary emission ratio over a voltage range from 100 to 3,000 volts varied from .7 to 1.35 and reached a maximum of 2.12 at 800 volts velocity. The curve C represents the mean value of similar films of the same thickness as B but preheated for various periods from 2 to 50 hours duration at temperatures between 630 to 1200° C. This curve shows a δ value of unity at 100 volts which increases to more than 3.0 at 600 volts and decreases uniformly in substantially a straight line up to 6,000 volts target voltage. The values for different heat treatments are between the unheated curve B and above the mean curve C over the same range of voltages and the represented curve is plotted for a six-interference rings film of tin oxide on a platinum base which was preheated at 750° C. for 50 hours.

Improved emission values may be attained with other thicknesses of the tin oxide in multiples of the initial film, each layer being oxidized the same as the first and preferably preheated before impact of primary electrons. The stability of the tin oxide coating or film on a base of platinum while constant over the large range of exciting voltages may also be duplicated on other metallic foundations such as nickel, copper, or alloy metals which are kept from excessive oxidation during deposition and also on insulating bases, for example, lime or soda glass, borosilicate glass and synthetic quartz. The film in varying thicknesses is highly conductive and will withstand high temperatures without decay or loss of efficiency.

While the invention has been disclosed in a particular application, it is, of course, understood that many variations may occur in the specific location of the secondary emission surface in devices of wide application and accordingly the invention is only limited within the scope of the appended claims.

What is claimed is:

1. An electron discharge device comprising a target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to said electrons and composed of tin oxide.

2. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at voltage velocities between 100 to 6,000 volts, and a secondary electron emitting surface on said target electrode exposed to said electrons and formed solely of tin oxide.

3. An electron discharge device comprising a target electrode, a collector in cooperative relation therewith, a cathode for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to said electrons and composed of a thin film of stannic oxide.

4. An electron discharge device comprising a metallic target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode with energy of the order of 600 volts, and a secondary electron emitting surface on said target electrode exposed to said electrons and comprising a film of tin

oxide having a thickness between 500 to 30,000 angstrom units.

5. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, a primary emitter for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to electron impact and comprising a thin film of tin oxide preheated between 630 to 950° C.

6. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at voltages between 100 to 6,000 volts, and a secondary electron emitting surface on said target electrode exposed to said electrons and comprising a film thickness of three to nine interference rings of stannic oxide preheated to 750° C.

7. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to said electron and comprising tin oxide having a thickness of three interference rings.

8. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to the electron stream and comprising a film of tin oxide having a thickness of nine interference rings.

9. An electron discharge device comprising a metallic target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to said electrons and comprising tin oxide having a secondary emission ratio above unity between 100 to 6,000 volts and a maximum of substantially 3.25 at 640 volts.

10. An electron discharge device comprising a platinum target electrode, a collector in cooperative relation therewith, means for propelling electrons against said target electrode at high voltages, and a secondary electron emitting surface on said target electrode exposed to said electrons and comprising a thick film of stannic oxide having an emissivity range in which the secondary emission ratio is between substantially 2.5 and 3.2 at 700 volts before preheating and after preheating at 750° C., respectively.

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