Oct. 31, 1950 J. BRAMLEY 2,527,981

SECONDARY-ELECTRON-EMISSION

Filed April 9, 1948 3 Sheets-Sheet 1

Fig. 1.

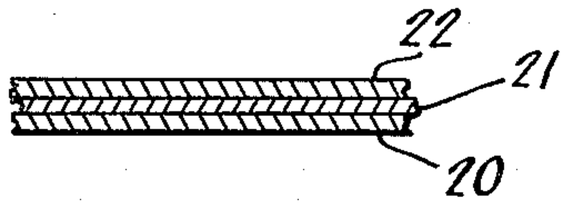

Fig. 2.

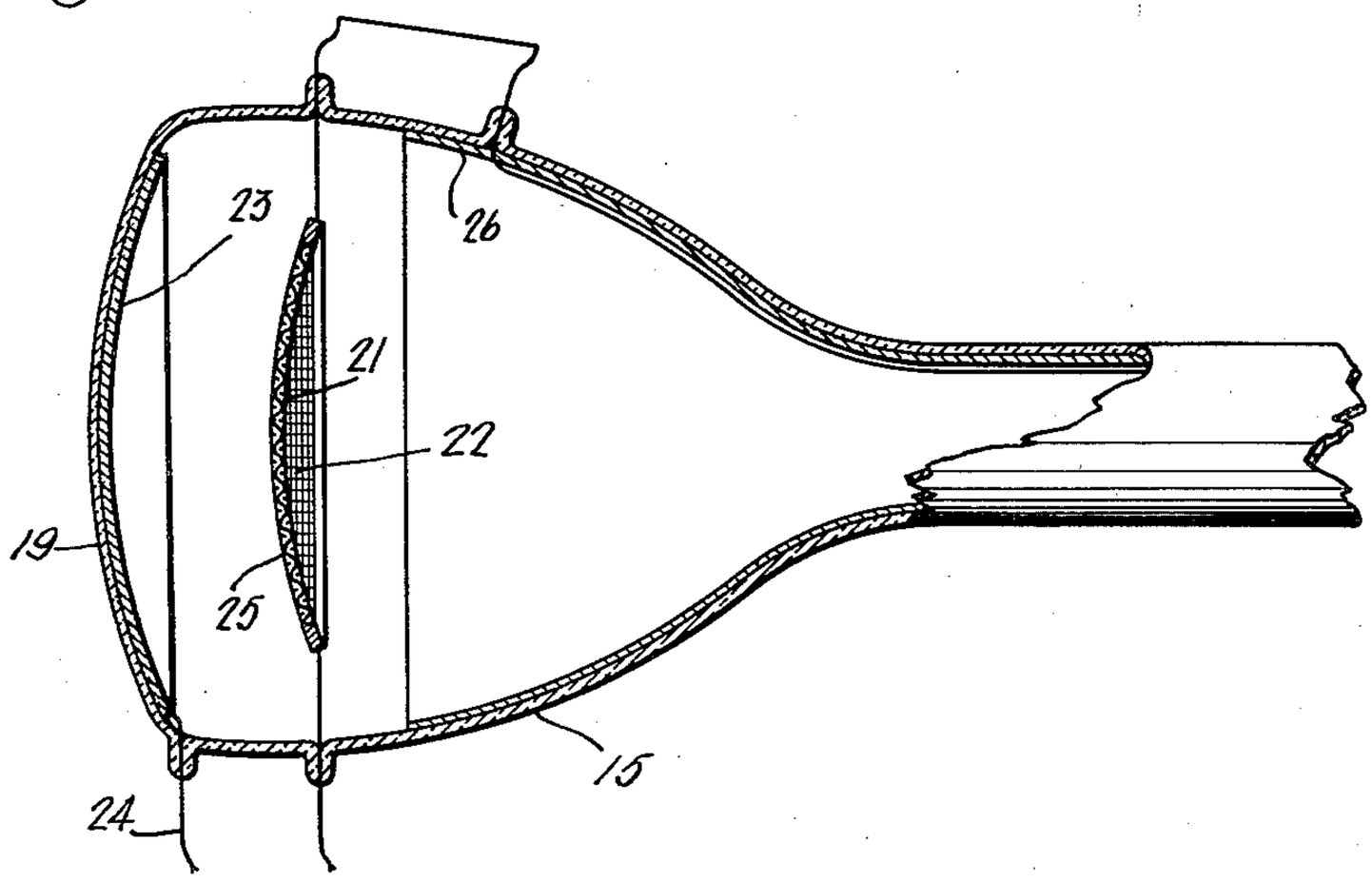

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Fig. 3.

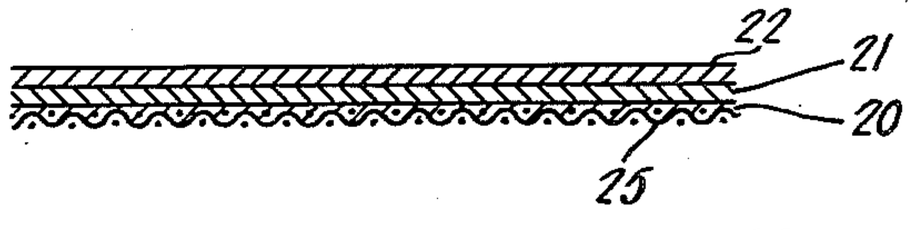

Fig. 4.

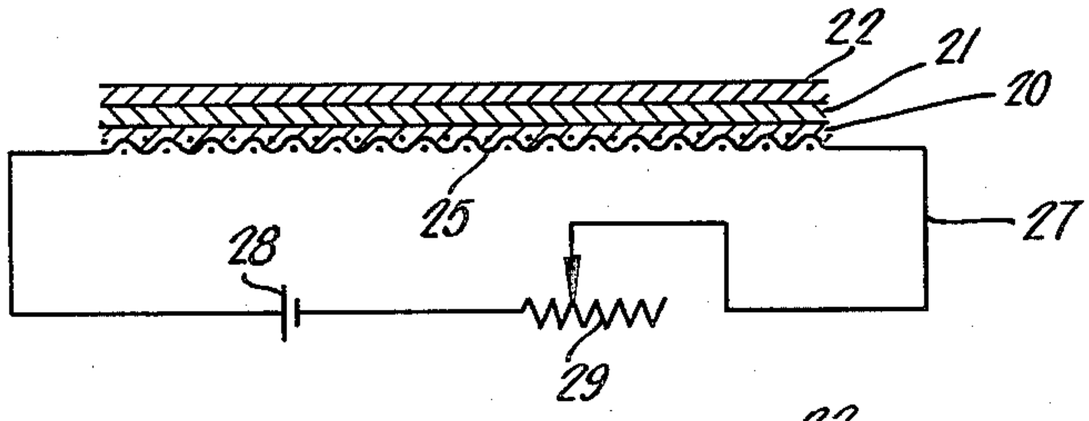

Fig. 5.

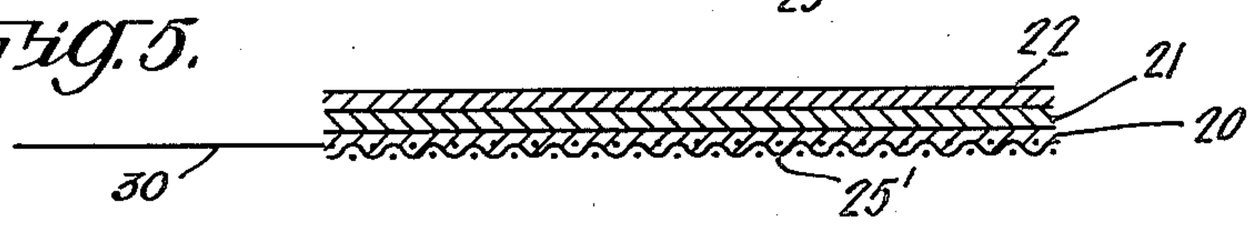

Fig. 6.

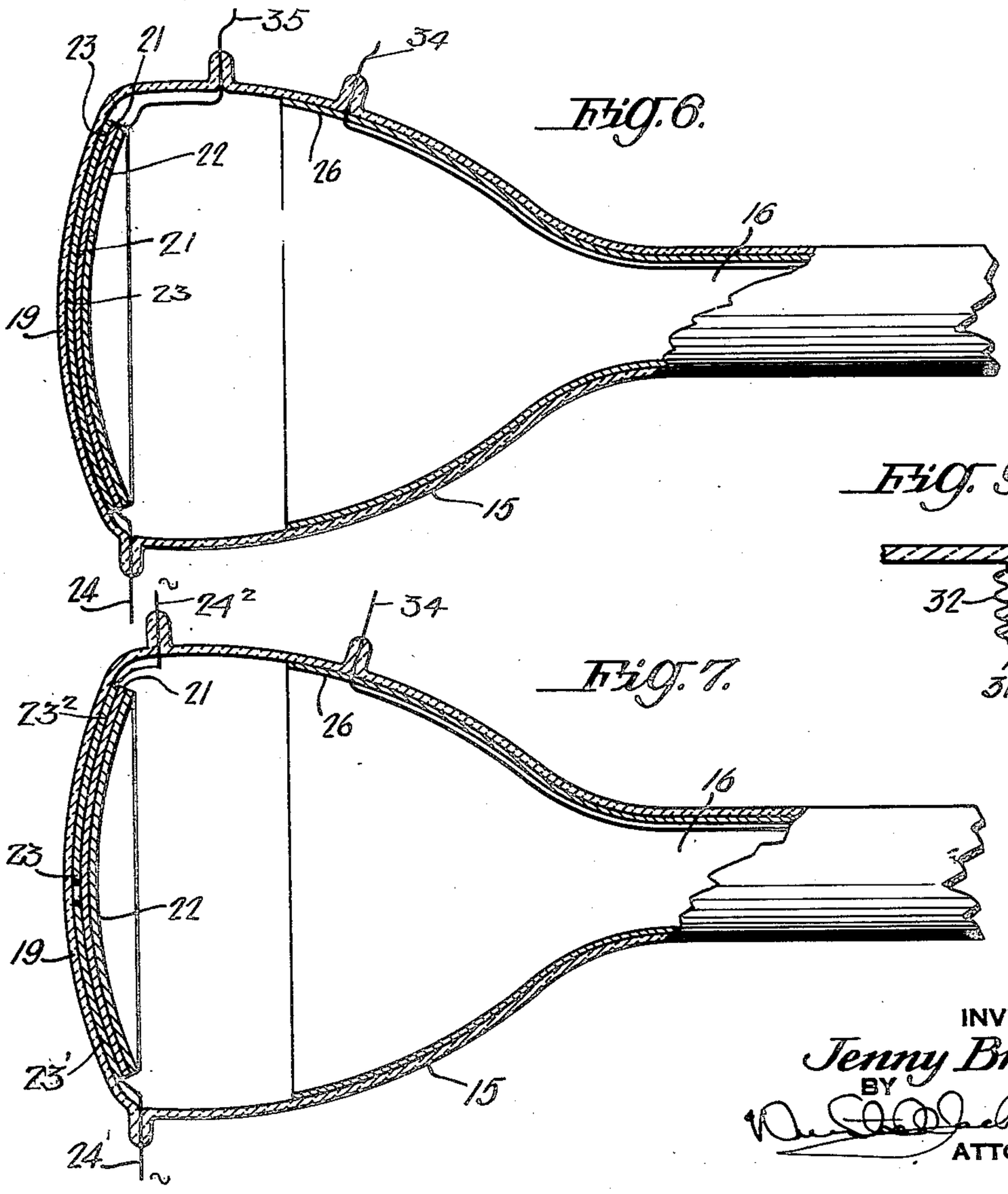

Fig. 9.

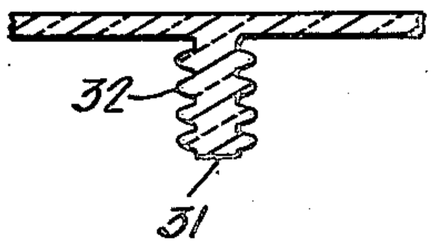

Fig. 7.

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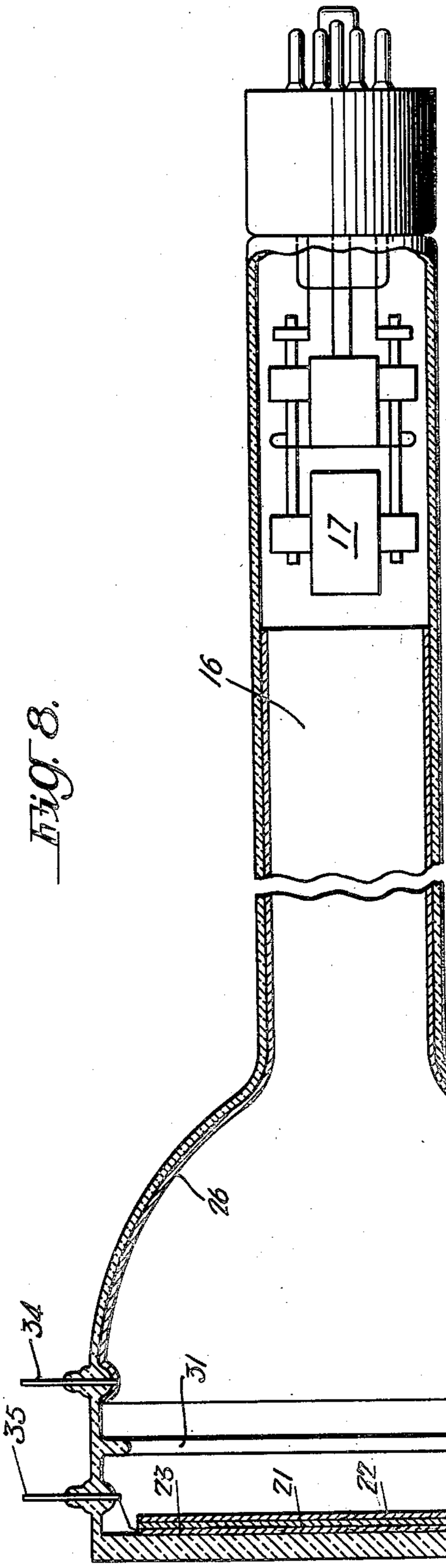

Fig. 8.

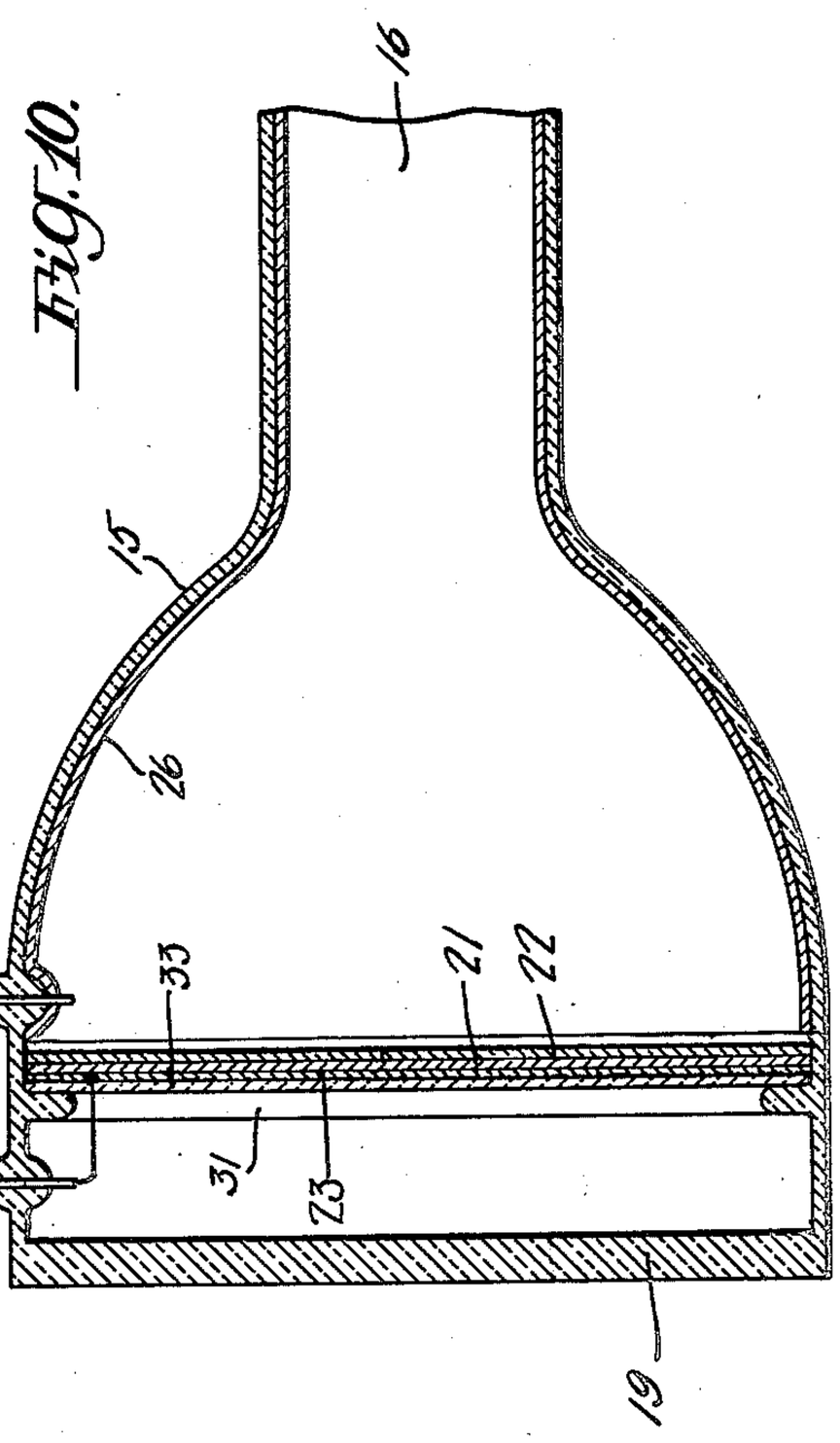

Fig. 10.

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Patented Oct. 31, 1950 2,527,981

UNITED STATES PATENT OFFICE

2,527,981

SECONDARY-ELECTRON EMISSION

Jenny Bramley, Long Branch, N. J.

Original application August 23, 1945, Serial No. 612,197. Divided and this application April 9, 1948, Serial No. 20,016

24 Claims. (Cl. 250—174)

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My invention relates to apparatus for secondary-electron-emission.

The present application is a division of my copending application for Secondary-Electron Emitting Surface, Serial No. 612,197, filed August 23, 1945.

The primary purpose of the invention is to obtain multiplication of secondary electrons much higher than that obtained in prior practice. This is accomplished in this invention by the proper construction of composite surfaces. One method is to interpose a layer of dielectric limited in thickness to 0.1 mm. and preferably not exceeding 0.03 mm. between a layer with at least moderately high secondary-electron-emissive properties (called henceforth the secondary-electron-emitting layer) on the one hand and a metallic base on the other hand. Suitable substances for the dielectric are oxides of titanium, copper, manganese, or aluminum, the latter having impurity centers, or crystals of alkali halides. For the secondary-electron-emitting layer the following substances may be used: beryllium or an alloy or oxide thereof, magnesium (oxidized), aluminum, or an alloy or oxide thereof.

A further purpose is to produce apparatus for increasing the emission of secondary electrons.

A further purpose is to obtain high multiplication in a secondary-electron-emitter without the undesirable features of photoelectric effect due to the presence of a photoelectric material, such as caesium, in the layer emitting secondary electrons.

A further purpose is to produce a secondary-electron-emitter of high multiplication while avoiding time lag between the start or stop of the primary current and the start or stop of high secondary electron emission.

A further purpose is to maintain close time coordination between a secondary-electron-emitter and the primary current by providing for the neutralization by electrons of the positive charge in the secondary-electron-emitting layer at a rate predetermined by the primary current.

A further purpose is to enhance the secondary-electron-emission of magnesium (oxidized) by baking it in vacuo at a temperature of 600° to 800° C. Other secondary electron emitters should be baked at appropriate temperatures predetermined by the nature of the emitter (that is, from 60° C. to a temperature of 300° C. below the melting point) in order to obtain close coordination between the primary current and the secondary electron emission together with the corresponding optimum value for the secondary electron

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emission ratio. It is possible either to minimize the time lag between the primary and secondary currents or to obtain the maximum value for the coefficient of secondary emission, but in general it is not possible to accomplish both purposes simultaneously. In the case of the alkali halides this temperature should range from 60° C. up to 250° C. in order to control the speed of the color centers induced in the alkali halides by primary electron bombardment, when these color centers move under the influence of an electric field.

A further purpose is to oxidize a metallic base, such as aluminum, copper or chromium, or an alloy thereof, or a corrosion resisting iron-chromium alloy (such as stainless steel), forming a dielectric, apply over it a secondary-electron-emitting layer, and expose the layers during operation for a short time to an elevated temperature predetermined by the coordination between the primary current and the secondary electron emission or by the value of the secondary electron emission ratio, which can be preassigned within limits for a time lag within the desired range.

A further purpose is to decrease conductivity along the layer of the secondary-electron-emitter in the composite surface as by granulating the surface into a mosaic.

A further purpose is to increase the scope of cathode ray beam tubes by employing a fine wire mesh with a surface having enhanced secondary-electron-emitting properties in a cathode ray beam tube in which there is a partially transparent metal film on the inside of the face plate. Aluminum constitutes a suitable choice for the metal film. The secondary-electron-emitting surface should surround the wires of the mesh, the whole structure constituting a perforated surface, which not only will allow the primary beam to go through it, but in its travel in a scanning path to find at all points a channel through which electrons can pass. The mesh must be at a negative potential with respect to the thin metal on the face plate. In another embodiment the fine wire mesh is used to support the three-layer secondary electron emitter, which should approximate a continuous surface. The base metal of the three-layer surface should in a variation of this embodiment make electrical contact with the fine metallic wire mesh used to support the secondary electron emitter. In another variation of this embodiment, the fine metallic wire mesh can be used to supply the heat to control the temperature of the three-layer

emitter. There is still another variation of this embodiment in which the three-layer secondary electron emitter can be supported in a non-metallic grid structure such as plastic or glass. In still another variation the aforementioned grid is replaced by a thin transparent sheet of plastic or glass. In those cases in which the dielectric of the composite secondary electron emitter has the optical properties desired for the examination of the pattern produced by the electron bombardment, the base metal should be in the form of a thin partially transparent film.

By proper choice of the emitting surface, the time lag between the primary current and the secondary emission from the wire mesh can be made comparable to the time between scanning frames. This is equivalent to a storage effect.

The drawings are useful in explaining the invention. They have been chosen for the purpose of clear illustration of the principles involved and to illustrate conventionally a few only of the possible embodiments of the invention. In the drawings like numerals refer to like parts.

Figure 1 is a diagrammatic section of a composite surface useful in explaining the invention.

Figures 2, 6, 7, 8 and 10 show cathode ray beam tubes having a glass envelope, the conventional electron gun and electrode system for accelerating the electrons, and if necessary focusing and deflecting them, being omitted in Figures 2, 6, 7 and 10, and suggested in Figure 8.

Figure 3 is a diagrammatic section of a composite surface in which the metal base makes electrical contact with a fine metallic wire mesh.

Figure 4 is a variation of Figure 3 in which the wire mesh supplies heat.

Figure 5 is a variation of Figure 3 in which the mesh is of plastic or glass.

Figures 6 and 7 are variations of Figure 2 omitting the grid and applying the secondary electron emitting element to the face plate.

Figure 8 is a further variation of Figure 2.

Figure 9 is a fragmentary variation of Figure 8.

Figure 10 is a view corresponding to Figure 2 showing a further variation.

One of the most important aspects of the invention relates to the production in electron tubes of extremely high emission of secondary electrons as a consequence of strong electrostatic fields initiated by bombardment with primary electrons of composite surfaces constructed in accordance with the invention. There must, of course, be a suitable source of primary electrons and these electrons should have a speed such that the ratio of the number of secondary electrons released from the secondary-electron-emitting element to the number of primary electrons of the beam impinging on the secondary-electron-emitting element is greater than unity, such velocity being furthermore such for cathode ray tubes that the time lag between the impact of the electrons in the scanning beam and the emission of secondary electrons is less than the time of persistence of vision.

The base, dielectric and secondary emitter are capable of being laid variously but always with the same resultant arrangement of layers and the same method of operation.

In the construction of tubes, the electrodes and other structural features of the tube may be applied one to another within an envelope of glass or metal as the case may be, in which case the "combination" between the several parts is

actually formed within the envelope itself by applying one part at a time until the construction under consideration has been completed, or the features or elemental parts may be correlated outside of the envelope with more or less completeness and be then introduced within the envelope as a member of the assembly, after which the tube is closed and evacuated.

The metallic base **20** in Figure 1 may consist of any desired solid metallic material. The metallic base is covered by an extremely thin layer **21** of dielectric. Suitable dielectric materials are: aluminum oxide Al_2O_3, provided it contains impurity centers, titanium oxide TiO_2, copper oxide, manganese oxide MnO, inorganic crystalline phosphors, inorganic vitreous phosphors, or an alkali halide, such as NaCl, KCl, LiCl. The alkali halides are inert and do not volatilize easily under the conditions of production of secondary emission.

The dielectric need not be a perfect insulator; it preferably will be a semi-conductor. The structure of the dielectric should preferably be very fine.

On the dielectric layer is deposited a thin (2 to 20 microns thick) layer **22** of a substance which is a good emitter of secondary electrons such as beryllium; beryllium oxide, BeO; alloys of beryllium, particularly alloys of berylium and copper; magnesium (oxidized); oxidized magnesium aloys; aluminum; alloys predominantly aluminum, such as duralumin of any of the recognized varieties, especially aluminum alloy 17S (Al 95%, Cu 4%, Mg. 0.5%, Mn 0.5%) or aluminum alloy 24S (Al 93.8%, Cu 4.2%, Mg 1.5%, Mn 0.5%), or the aluminum magnesium (such as 10% or 30%) alloys, or the aluminum-beryllium alloys, of which the one containing 30% beryllium appears the most efficient. Aluminum base alloys of silicon, and aluminum base alloys of copper may be used. In the aluminum base alloys of beryllium the content of beryllium should be between 25% and 40% and the combined content of magnesium, molybdenum, and zirconium should not exceed two percent; oxides of aluminum base alloys of beryllium may be used. Also oxidized aluminum base alloys of beryllium having magnesium as a preconstituent may be employed. Among the above, the duralumins are unexpectedly effective out of all proportion to any characteristics previously suspected and greatly exceed pure aluminum in multiplication.

When this top or secondary-electron-emitting layer **22** is struck by primary electrons under suitable potential conditions, it emits a large number of secondary electrons and thus becomes positively charged and creates a strong electrostatic field between the metallic base and the dielectric layer **21**. This electrostatic field pulls out electrons from the metallic base **20** through the dielectric thus producing a high multiplication of electrons. The strong fields across the dielectric which have been discussed so far, were produced by secondary electron emission from the secondary-electron-emitting layer. However, if the secondary-electron-emitting layer is conducting, it is possible to connect it electrically to a source of electrical power and obtain the same results, namely, the production of internal secondaries in the dielectric by the primary beam, the production of electrons in the dielectric by strong field emission from the metal base, and in certain cases, such as alkali halide dielectrics, the drift of color centers.

The combined thickness of the dielectric layer and of the layer emitting secondary electrons must be very small, the desirable range being from 2 to 20 microns. While not in every case essential, this range of thickness should be used for best results.

One of the problems in the prior art has been to cause the secondary-electron emission to stop and start either in coincidence with the primary current or after only a brief and controllable time interval. Malter (Marconi) British Patent 481,170, September 7, 1936, uses caesium and is troubled by time lag between the start of the primary current and the start of the high secondary-electron-emission, as well as between the stopping of the primary current and the stopping of the secondary emission. (Malter, Physical Review, vol. 49, p. 478 and p.879 (1936).) Furthermore, caesium deteriorates by volatilization in vacuo and causes objectionable photoelectric effects, which militate against the use of the layer as an emitting surface in a photomultiplier tube.

In the present invention, the electron-emitting layer is non-photoelectric, and many advantages and avoidance of much difficulty are thereby obtained.

In order to prevent excessive time lag, the positive charge in the secondary-electron-emitting layer **22** must be neutralized by electrons from the dielectric **21** very quickly, but not quickly enough to interfere with extraction of secondary electrons by the electrostatic field. The extraction time has been estimated as about 10^{-14} seconds.

The dielectric layer **21** may be deposited by spraying, settling, evaporation, or similar methods carried out at suitable temperatures as well as by oxidation, as later explained. The secondary-electron-emitting layer can be deposited on the dielectric by dusting, evaporation, settling, or the like. I have discovered that in order to produce the high field necessary for electron extraction from the metallic base under the conditions of cold emission (about 1,000,000 volts per centimeter) the thickness of the dielectric layer is of importance. A voltage due to secondary-electron emission of more than a few thousand volts is not obtained in practice. For best results the thickness should be approximately 0.03 millimeter, and in any case the thickness of the layer should not exceed 0.1 millimeter. No limit on thinness is necessary provided the dielectric functions.

The invention is operative in its broader phases provided the metallic base, dielectric layer, and secondary-electron-emitting layer are as described, without further precautions to avoid time lag, but for best results special precautions to avoid time lag should be taken. There are several ways, which I have discovered to overcome this trouble.

One way of assisting in overcoming time lag is to deposit the three-layer secondary-electron-emitting surface in such a way that its temperature can be controlled within narrow limits. This can be accomplished in a number of ways. One way is to make the base metal very thin so that it has a very small heat content and support it on a heat insulator transparent to infra red radiation, such as glass, as for example the face plate of a cathode ray tube, mica, or certain plastics. The temperature is then controlled by the amount of infra red radiation received by the composite surface. Another way is to support the very thin metallic base on a support,

which itself has a very low heat content, such as a very thin nonmetallic insulating (plastic or glass) film, which is in turn supported by a wire mesh. On being heated by a source of current, this wire mesh will transmit its heat to the secondary electron emitter. Still another way, which can be used either by itself or in combination with either infra red or electrical energy, is to make the heat content of both the secondary-electron-emitting surface and of its support very low, as by supporting a very thin metallic base on a very thin plastic or glass film supported in turn on a fine plastic or glass mesh or support, so that the heat produced by the primary beam on bombarding the surface is sufficient to raise the temperature to the desired range.

It is desirable in many cases to have a means of varying the strength of the field across the dielectric from one point on the outer surface of the secondary-electron-emitting layer to another. This can be accomplished to some extent by the mosaic structure of this layer, which enables different island regions of the secondary-electron-emitting layer to assume different potentials. These island regions are small in extent. The value of the differences in potential will depend on the degree of the mosaic structure and on the resistivity of the dielectric, two factors determining the extent of insulation of the islands from each other. This division of the secondary-electron-emitting composite surface can be carried even further. The surface of the secondary-electron-emitting layer can be divided into separate regions not only to have a means for varying the field strength across the dielectric but for the purpose of heating the separate regions to different temperatures. Since the properties of the dielectric, such as the mobility of color centers in alkali halides, depend to a marked degree on the temperature, this variation in temperature can be used to achieve, for example, different degrees of coloration in alkali halide dielectrics. This division can be carried still further; the base metal can be divided into insulated regions which can be maintained at different potentials.

Where the secondary-electron-emitter is beryllium, it has been successfully applied to the tube element by evaporation in vacuo from electrically heated tantalum spirals which serve as supports and heaters. It does not matter whether the beryllium is oxidized or not, since the metal and oxide are equally good as secondary emitters.

Where magnesium is used as a secondary-electron-emitter, the oxidation is essential, as the unoxidized metal is not a good emitter. The metal will, however, oxidize rather readily in air. I have discovered that the effectiveness of magnesium (oxidized) as a secondary-electron-emitter is greatly improved by the step of baking in vacuo at a temperature of from 600° to 800° C. The reason for the improved results from the baking in vacuo is thought to be at least partly due to the migration of magnesium into the surface portion of the dielectric, and the fact has been clearly demonstrated.

Where the metallic base is made of a metal which forms an adherent oxide film self limited in thickness to about 50 Angstroms, the oxide can be utilized for the dielectric. Suitable metallic base materials may consist of aluminum or aluminum alloys, such as aluminum-copper up to 11%; aluminum - copper (4 to 4.2%) — manganese (0.5%)—magnesium (0 5 to 1.5%); aluminum-magnesium (10%); aluminum-copper (4%)—

silicon (3%); chromium; alloys predominantly consisting of chromium (chromium-copper); copper, alloys predominantly consisting of copper (bronze, brass, muntz metal), and corrosion-resisting iron-chromium (14%) alloys.

The invention can be usefully applied to electron beam tubes and in particular to image converter, or cathode ray tubes, or light valves to intensify the images produced by electron impact on fluorescent or light valve screens. While the example given below has been directed particularly to cathode ray tubes, it will be evident to those skilled in the art that it can be applied equally well to image converters and light valves.

For cathode ray tubes the metallic film on the inside of the face plate must be capable of transmitting at least 85% of the light impinging upon it. It is desirable to have a means of adusting the metallic film to a definite potential. Several views show a cathode ray tube having an envelope **15** and a cathode ray beam channel **16** from a gun **17** (Figure 8) to a metallic layer **23** on a face plate **19**. For example, in Figure 2, the conducting film **23** on the interior surface of the face plate of the cathode ray beam tube is connected to electrode **24**. The potential of the metallic grid **25** is maintained at the value of the anode potential by connecting the grid **25** to the colloidal graphite coating **26**. The grid **25** must be coated and the composite surface prepared to produce an enhanced secondary-electron-emission. The grid **25** forms the metallic base of the secondary-electron-emitter. Of course, the conducting film **23** and the electrical connection to the electrode **24** must be insulated from grid **25**.

In one of the embodiments of the invention the base metal layer **20** makes electrical contact with the fine metallic wire mesh of the grid **25**, the dielectric layer **21** and secondary-electron-emitting layer **22** being deposited on the metallic base **20** on the side toward the electron beam. See Figure 3.

As shown in Figure 4, the fine metallic wire mesh of the grid **25** can itself supply the heat to control the temperature of the three-layer emitter. To suggest this, without limitation thereto, I have shown a heater circuit **27** connected to an element of the mesh **25**, and including a source of electric power **28** and a control resistor **29**.

In another variation of the invention the three-elements secondary-electron-emitter is supported on a plastic, mica or glass grid **25'** as shown in Figure 5, the electrical connection **30** being made to the base metal **20**, and the dielectric **21** and secondary-electron-emitting layer **22** being applied thereon. Plastic for the grid may be phenol-formaldehyde, linear polyamide, urea-formaldehyde, or the like.

Of the three embodiments of the invention illustrated in Figures 3, 4, and 5, especially easy to carry out in practice is the embodiment shown in Figure 5. The base metal **20** may be varied in thickness within rather large limits depending on the particular application for which the tube is designed. For applications involving cathode ray beam tube construction, the base metal **20** may be deposited so thinly that its transmission for light is high.

However, in many applications the power requirements of the tube, particularly of the heating means in a cathode ray beam tube, make it possible to dispense with mesh **25** provided that the secondary-electron-emitter is made part of the coating on the face plate. Then the transparent conducting film **23** on the interior surface of the face plate serves as the metallic base of the enhanced composite secondary electron emitter.

Figure 6 illustrates a tube similar to that shown in Figure 2 without a grid, in which the partially transparent conducting film **23** provides the base for a dielectric layer **21** and a secondary-electron-emitting layer **22**. The terminal **24** is connected to the film **23**. As shown in the drawing, the secondary-electron-emitting layer **22** is connected electrically to an electrode **35** so that it can be maintained at a different potential from the metallic base **23**. In this embodiment the potential of the secondary-electron-emitting layer **22** and of the conducting coating **26** can be the same, but if the electrodes **34** and **35** and the surfaces **22** and **26** are suitably insulated by means shown in Figure 8, this need not be so. If the potentials of surfaces **22** and **26** are the same, in many instances the electrical connection between them can be made internally without the necessity of having electrode **35**.

Inorganic crystalline phosphors, inorganic vitreous phosphors, and the alkali halides are of particular interest as dielectrics over the base metal, while aluminum and magnesium, in which last metal the surface is oxidized, are of particular interest for the secondary-electron-emitting layer over the dielectric.

According to another form of realization of the apparatus according to this invention as described in the next to the last paragraph, the metallic base of the secondary-electron-emitter, which is shown as the coating **23** in Figure 2, may be divided into separate sections insulated from one another, which provide the base for the dielectric layer **21** and the secondary-electron-emitting layer **22**. These may also be divided into sections corresponding to the divisions of the conducting film **23**. Figure 7 shows a tube in which the terminals **24'** and **24²** are connected electrically to the separate sections **23'** and **23²** of the conducting film, on which are superimposed the dielectric layer **21** and the secondary-electron-emitting layer **22**. The latter is shown as a unit insulated by the dielectric layer **21**.

In many applications, e. g. Figure 6, the potential on the partially transparent conducting film **23** may be negative with respect to the anode potential, but for best performance it is often advisable to maintain this conductor **23** at an alternating potential of such frequency and magnitude with respect to the anode potential that the electrons are not trapped in interstitial positions in the dielectric. This arrangement is also advantageous for the method illustrated in Figure 7 where the alternating component of the potential of the two sections of the conductor **23'** and **23²** should have different phase angles with respect to each other.

Since the operation of a construction such as Figure 6 depends on the orientation of the electric fields, the shape of the funnel and of the face plate must be adapted to conform to the electrostatic potential lines so that the raster on the face plate should not be distorted. One way of accomplishing this is to have the end of the funnel in the shape of a cylinder with a flat face plate sealed on to the end of this cylinder. It is obvious that the funnel must have another shape if the face plate has a radius of curvature comparable to its diameter. Since the film **23** on the interior of the face plate is an equipotential surface which may be maintained at a different po-

tential than the conducting coating 26 of the funnel, the system of equipotential surfaces can be made to approximate those near the end of the low voltage cylinder of a two cylinder electrostatic lens. The system of mesh 25 or film 23 held at different potentials with regard to the conducting anode coating 26 of the tube (aquadag is a particularly effective coating) has a profound effect on the electron trajectories. In those cases where images produced by primary beam bombardment of the enhanced secondary-electron-emitting surface are under observation, the image may be considerably altered from those images which would be observed if the mesh or film were held at anode potential. The effects of these electrostatic lens systems on the electron trajectories are subject to calculation. Typical examples of this technique are shown in V. E. Cosslet, Introduction to Electron Optics (Oxford 1946), notably chapter II, The Electrostatic Field, where Figure 18, page 26, gives the potential distribution in the symmetrical two-cylinder lens, and chapter III, Electrostatic Focusing, with Figure 31, giving the trajectories and cardinal points in a two-cylinder lens. By proper choice of the potential difference the electron trajectories become such that the spot size is substantially the same as that in a system where the film 23 is at the same potential as the conducting coating 26.

In carrying out the invention provision may have to be made for maintaining—without undue leakage or breakdown—the potential difference in the short distance between the end of the conducting coating 26 at anode potential, and the conducting film 23. This distance has to be short in order to simulate the conditions in a typical cathode ray tube. Since thousands of volts may have to be maintained over this short distance ranging from ½ to 1 inch, the glass path should be increased several times over this value. The same is true for the vacuum path between the ends of the conducting coating 26 at anode potential and the film 23. One way of accomplishing this end is to form an insulator (glass) barrier protruding into the tube but not so far that it intercepts the electron beam as it scans over the face plate. If the barrier 31 shown in its simplest form in Figure 8 is corrugated as shown at 32 in Figure 9 like the insulators used in high tension lines, then the glass path is still further increased between the end of the conducting coating 26 at anode potential and the composite secondary-electron-emitting surface in which the base metal is constituted by the partially transparent conducting film maintained at the potential of electrode 35 by electrical connection means. The secondary-electron-emitting layer 22 is shown electrically insulated by the dielectric 21.

A further variation of the tube of Figure 8 is shown in Figure 10. In this form the tube is conveniently contoured as shown in Figure 8 but is provided with a nonmetallic insulating (plastic or glass) film 33 which on its side directed toward the electron beam supports the composite secondary electron emitting surface. The base metal of the three element composite surface shown in the figure as the partially transparent conducting film 23 is connected to the terminal 35 which may be maintained at a different fixed potential from the conducting coating 26, e. g. aquadag (colloidal graphite).

In order to decrease conductivity along the layer of the secondary-electron-emitter in the

composite surface such surface may be granulated into a mosaic. This can be done by firing in a hydrogen atmosphere at a temperature above 600° C. and below the softening point of the metal to reduce impurities and roughen the surface.

An alternate technique for producing the mosaic is to expose the composite surface (metallic base, oxide, and secondary-electron-emitting layer) abruptly and briefly to a temperature in the range from 600° to 800° C. for aluminum and higher or lower depending on the melting point for the other metals and alloys mentioned. For best results the exposure should be limited to a few seconds in order to insure that the secondary-electron-emitting layer (for example beryllium) be in the form of a well separated mosaic. The mosaic structure increases the surface of the dielectric exposed to the primary beam and reduces conductivity in the plane parallel to the metallic base.

There is no exact temperature at which beading or mosaic formation occurs, but rather a range as set forth within which the phenomenon is evidenced. The extent of mosaic formation is influenced by such factors as oxide film thickness and heat capacity of the metallic base.

In operation the semi-conductor 21 of Figures 1 and 2 shows metallic conduction properties under the action of the primary-electron-beam. For each electron of the primary beam many electrons are raised to the conduction band of the extrinsic semi-conductor forming the dielectric 21. In the embodiment shown in Figure 2 of this application, part of these conducting band electrons are emitted from the composite surface by the secondary-electron-emitting layer 22 and are collected by the metallic film 23. In the embodiment shown in Figure 6 part of these conduction electrons are collected by the contiguous secondary-electron-emitter layer 22 and conducted to the electrode 35. The secondary-electron-emitting layer 22 functions then as a conductor and as a collector of only internal secondary electrons produced in the extrinsic semiconductor by the primary beam.

In view of my invention and disclosure variations and modification to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In an electron tube, a multiplier element comprising a metallic base, a secondary-electron-emitting layer and a semi-conductor dielectric limited in thickness to 0.1 mm. interposed between the metallic base and the secondary-electron-emitting layer and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors.

2. In an electron tube, a multiplier element comprising a metallic base, a semi-conductor dielectric layer limited in thickness to 0.1 mm. on the base and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors,

alkali halides and inorganic vitreous phosphors, and a secondary electron emitting layer from 2 to 20 microns thick on the dielectric and selected from the class consisting of beryllium, beryllium oxide, magnesium (oxididzed), oxides of magnesium base alloys, aluminum, aluminum base alloys of silicon, aluminum base alloys of magnesium, aluminum base alloys of copper, aluminum base alloys of beryllium, in which last alloy the content of beryllium is between 25% and 40% and in which aluminum base alloy of beryllium the combined content of magnesium, molybdenum, and zirconium does not exceed two percent, oxides of aluminum base alloys having as a preconstituent beryllium, aluminum base alloys of beryllium having as a preconstituent magnesium, in which last alloy the surface is oxidized.

3. In an electron tube, a multiplier element comprising a metallic base, on the base a semiconductor dielectric layer limited in thickness to 0.1 mm., whose conductivity is artificially increased under bombardment by the primary electron beam, and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a non-photoelectric secondary-electron-emitting layer on the dielectric, the positive charge in the secondary-electron-emitting layer being neutralized at a rate predetermined by the primary beam.

4. In an electron tube, a multiplier element comprising a metallic base, on the base a semiconductor dielectric layer whose conductivity is artificially increased under bombardment by the primary electron beam selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors and limited in thickness to 0.1 mm., and on the dielectric a secondary-electron-emitting layer from 2 to 20 microns thick selected from the class consisting of beryllium, beryllium oxide, magnesium (oxidized), oxides of magnesium base alloys, aluminum, aluminum base alloys of copper, aluminum base alloys of beryllium, in which last alloy the content of beryllium is between 25% and 40% and in which aluminum base alloy of beryllium the combined content of magnesium, molybdenum, and zirconium does not exceed two percent, oxides of aluminum base alloys having as a preconstituent beryllium, aluminum base alloys of beryllium having as a preconstituent magnesium, in which last alloy the surface is oxidized.

5. A cathode ray beam tube including a face plate and in close proximity to the face plate a layer, a metallic base on the layer, over the base a semi-conductor dielectric layer limited in thickness to 0.1 mm. and selected from the class consisting of the oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides, and inorganic vitreous phosphors, and over the dielectric a secondary-electron-emitting layer selected from the class consisting of beryllium, beryllium oxide, magnesium (oxidized), oxides of magnesium base alloys, aluminum, aluminum oxide, aluminum base alloys of silicon, aluminum base alloys of magnesium, aluminum base alloys of copper, aluminum base alloys of beryllium, in which last alloy the content of beryllium is between 25% and 40% and in which aluminum base alloy of beryllium the combined content of magnesium, molybdenum, and zirconium does not exceed two percent, oxides of aluminum base alloys having as a preconstituent beryllium, aluminum base alloys of beryllium having as a preconstituent magnesium, in which last alloy the surface is oxidized, and electrode means connected to the metallic base.

6. A cathode ray beam tube having a reticulated surface adapted to permit passage of primary and secondary electrons through it, a layer of dielectric upon the reticulated surface selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of magnesium, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a secondary-electron-emitter upon the dielectric.

7. A cathode ray beam tube having a grid, a thin partially transparent continuous layer of metal extending over the grid, and constituting the metallic base of a composite secondary-electron-emitting surface supported thereon, a dielectric deposited upon the layer of metal, and a secondary-electron-emitting layer upon the dielectric.

8. In a vacuum tube, a metallic grid, a thin partially transparent layer of metal supported on and in electrical contact with the grid forming the metallic base of a composite secondary-electron-emitting surface, a dielectric deposited upon the layer of metal and a secondary-electron-emitting layer upon the dielectric.

9. A vacuum tube having a plastic layer, a layer of metal constituting the metallic base of a composite secondary-electron-emitting surface supported by the plastic layer, a dielectric deposited upon the layer of metal, and a secondary-electron-emitting layer upon the dielectric.

10. A cathode ray beam tube having a face plate, means for generating an electron beam, a partially transparent non-metallic insulating layer extending across the tube between the means for generating the beam and the face plate and a secondary-electron-emitting composite surface on the partially transparent layer comprising a metallic base, a semi-conductor dielectric layer on the metallic base selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, the secondary-electron-emitting layer being located on the sides facing the means for generating the electron beam.

11. A cathode ray beam tube having a face plate, means for generating an electron beam, a transparent plastic layer extending across the tube between the means for generating the beam and the face plate and a secondary-electron-emitting composite surface on the transparent layer comprising a metallic base, a semi-conductor dielectric layer on the metallic base selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, the secondary-electron-emitting layer being located on the sides facing the means for generating the electron beam.

12. A cathode ray beam tube having a face

plate, means for generating an electron beam, a transparent glass layer extending across the tube between the means for generating the beam and the face plate and a secondary-electron-emitting composite surface on the transparent glass layer comprising a metallic base, a semi-conductor dielectric layer on the metallic base selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, the secondary-electron-emitting layer being located on the sides facing the means for generating the electron beam.

13. A cathode ray beam tube having a face plate, means for generating an electron beam, a partially transparent non-metallic insulating layer extending across the tube between the means for generating the beam and the face plate, a secondary-electron-emitting composite surface on the partially transparent layer including a partially transparent metal layer as a metal base, a semi-conductor dielectric layer on the metallic base selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, the secondary-electron-emitting composite surface being located on the sides facing the means for generating the electron beam and a terminal connected to such partially transparent metal layer.

14. A cathode ray beam tube having a face plate, means for generating an electron beam, a conducting coating at anode potential on the interior of the tube around the beam, a composite secondary-electron-emitting surface including as a metal base a partially transparent conducting film on the interior of the face plate and an insulator barrier extending inwardly between the conducting coating at anode potential and the partially transparent conducting film.

15. A cathode ray beam tube having means for generating an electron beam and a face plate, a partially transparent conducting film on the interior of the face plate, constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited upon the film and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a secondary-electron-emitting layer upon the dielectric directed toward the electron beam.

16. A cathode ray beam tube having means for generating an electron beam and a face plate, a partially transparent conducting film on the interior of the face plate, constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited upon the film and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, a secondary-electron-emitting layer upon the dielectric directed toward the electron beam and a terminal connected to the partially transparent conducting film.

17. In an electron tube, a multiplier element

having a plurality of insulated metallic bases provided with separate terminals, on and between each base a semi-conductor dielectric layer whose conductivity is artificially increased under bombardment by the primary electron beam, limited in thickness to 0.1 mm., and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors and on the dielectric a secondary-electron-emitting layer from 2 to 20 microns thick.

18. In an electron tube, a multiplier element having a plurality of insulated metallic bases provided with separate terminals, on and between each base a semi-conductor dielectric layer whose conductivity is artificially increased under bombardment by the primary electron beam, limited in thickness to 0.1 mm., and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors on the dielectric a secondary-electron-emitting layer from 2 to 20 microns thick, and alternating current sources at different phase displacements connected to the terminals.

19. A cathode ray beam tube having means for generating an electron beam and a face plate, a partially transparent conducting film on the interior of the face plate, constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited upon the film and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, a secondary-electron-emitting layer upon the dielectric directed toward the electron beam, and separate terminals connected to the partially transparent conducting film and to the secondary-electron-emitting layer.

20. A cathode ray beam tube having means for generating an electron beam and a face plate, a partially transparent conducting film on the interior of the face plate, constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited on the film and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of magnesium, inorganic crystalline phosphors, alkali halides, and inorganic vitreous phosphors, a secondary-electron-emitting layer upon the dielectric directed toward the electron beam, and a conducting coating at anode potential on the interior of the tube around the beam.

21. An electron tube having a source of electrons, an electrically conducting metallic electrode constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited upon the electrode, and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a secondary-electron-emitting layer upon the dielectric directed toward the source of electrons.

22. An electron tube having a source of electrons, an electrically conducting metallic electrode constituting the metallic base of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited upon the electrode, and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of manganese, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a mosaic of secondary-electron-emitting material upon the dielectric directed toward the source of electrons.

23. A cathode ray tube having means for generating an electron beam and a face plate, a plurality of insulated metallic bases of partially transparent conducting film on the interior of the face plate constituting the metallic bases of a composite secondary-electron-emitting surface, a semi-conductor dielectric deposited on each base and selected from the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of magnesium, inorganic crystalline phosphors, alkali halides, and inorganic vitreous phosphors, a secondary-electron-emitting layer on each dielectric directed toward the electron beam, and

separate terminals connected to the partially transparent metallic bases.

24. In an electron tube, a multiplier element having a plurality of separate insulated metallic bases provided with separate terminals, on each base a semi-conductor dielectric layer of the class consisting of oxides of aluminum containing impurity centers, oxides of copper, oxides of titanium, oxides of magnesium, inorganic oxides of magnesium, inorganic crystalline phosphors, alkali halides and inorganic vitreous phosphors, and a secondary-electron-emitting layer on each dielectric.

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