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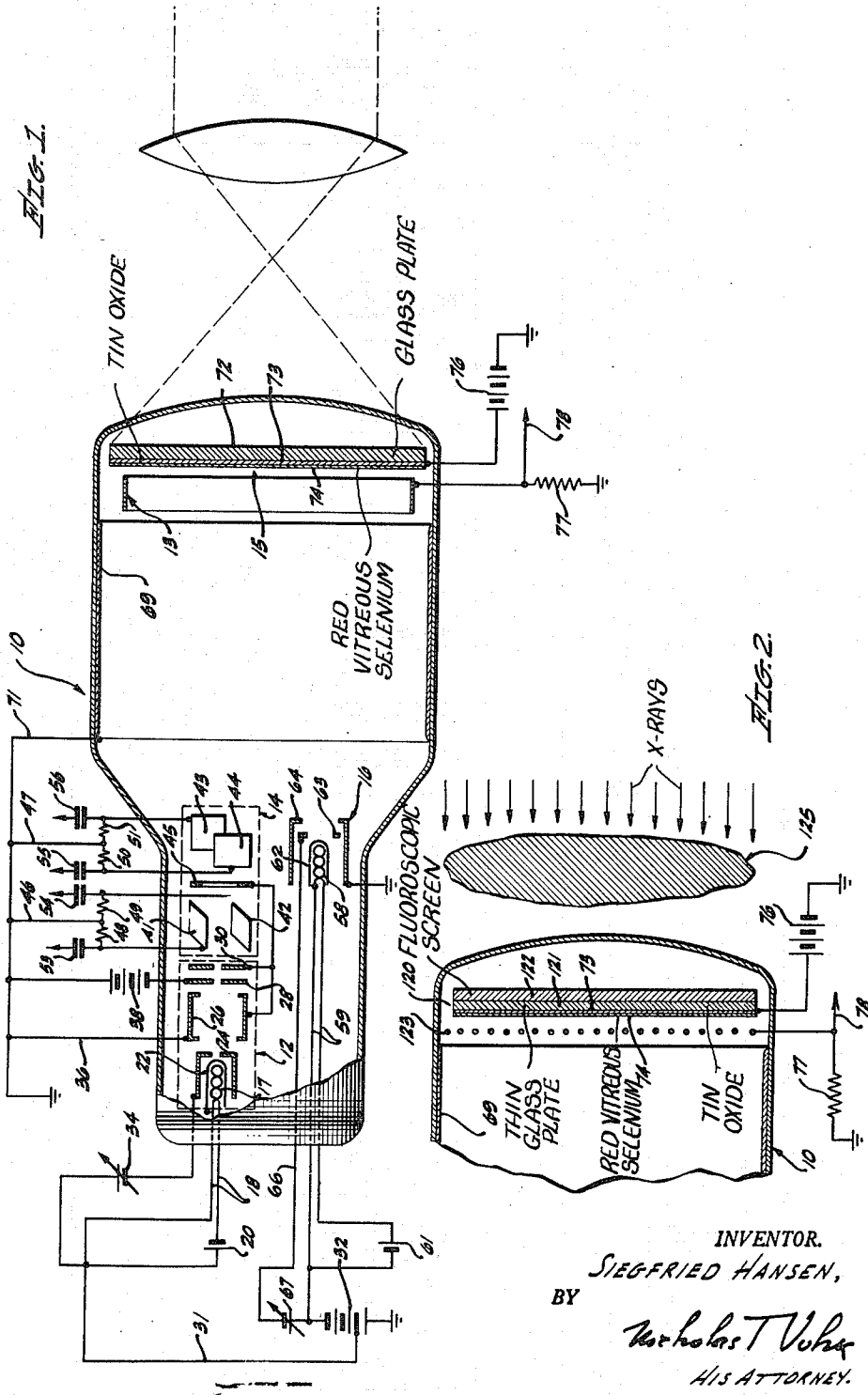
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2,866,918

ELECTRONIC CAMERA TUBE

Filed June 30, 1953

2 Sheets-Sheet 1



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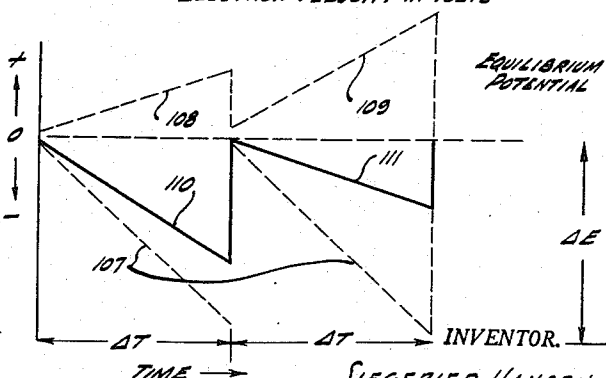
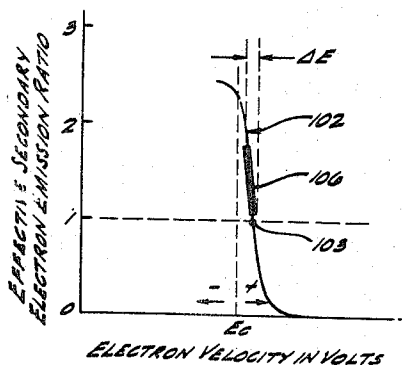
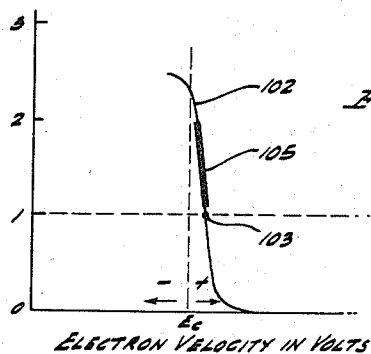
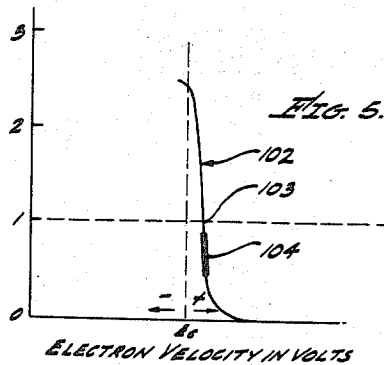
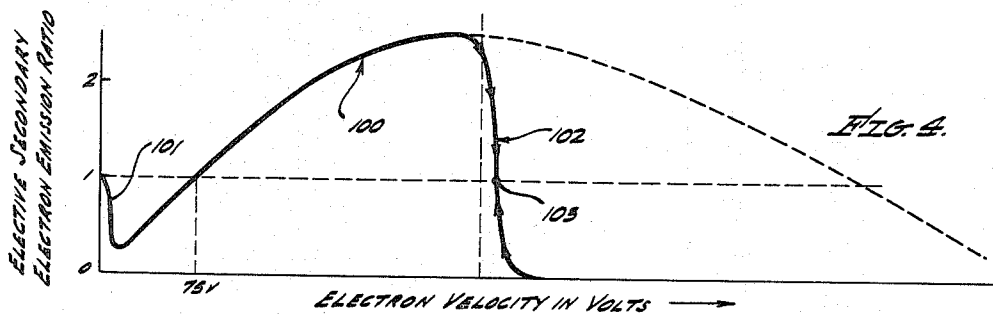
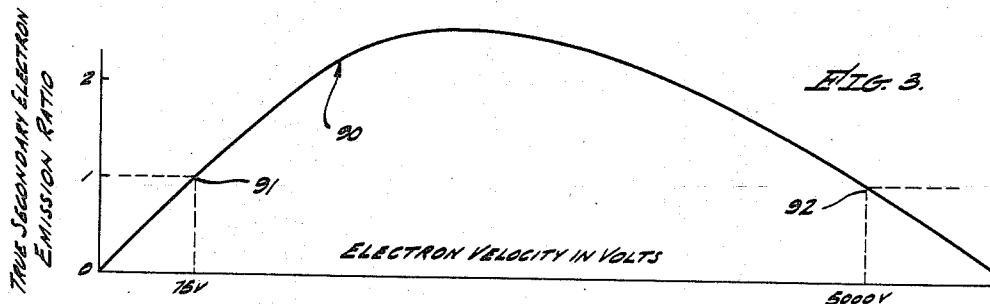


FIG. 7.

FIG. 8. BY

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2,866,918

ELECTRONIC CAMERA TUBE

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6 Claims. (Cl. 315—11)

This invention relates to television type camera tubes and more particularly to a camera tube wherein a photoconductive process is incorporated that effects the conduction of electric charges in the form of holes through a photoconductive layer towards a surface that is scanned by an electron beam of elemental cross sectional area and uniformly bombarded by high energy flood electrons.

There are many types of television camera tubes of the type that employ a photoconductive layer. A tube of this type generally includes a collector electrode disposed adjacent to one surface of the photoconductive layer and has means for scanning this surface with an electron beam of elemental cross sectional area having a velocity such that the scanned elemental areas of the surface will be charged to an equilibrium potential that is either slightly positive with respect to the potential of the collector electrode, or equal to the potential of the source of the electrons of the beam.

When in operation, an image is focused on a surface of the photoconductive layer and appropriate potentials applied across the layer so that charges will be deposited on elemental areas of the scanned surface in proportion to the light intensity of the image in register therewith. Hence, when an elemental area of the surface is scanned by the electron beam, the number of secondary electrons emitted from the elemental area and collected by the collector electrode will be indicative of the amount by which the elemental area was charged to reach the aforementioned equilibrium potential. An electrical signal representative of the image focused on the surface of the photoconductive layer is thus produced.

An undesirable effect in camera tubes of this type arises when the electron beam charges an elemental area of the photoconductive surface in a negative direction towards the equilibrium potential. This effect is generally referred to as the redistribution of electrons and is caused by a considerable portion of the secondary electrons emitted from a bombarded elemental area of the photoconductive surface returning to the more positive adjacent areas of the surface. Once back on the photoconductive surface, the secondary electrons are equivalent to electrons produced by the photoconduction process and thus act to reduce contrast and resolution in the image signal.

One method used to minimize the effect of redistribution of electrons, is to choose the potentials applied across the photoconductive layer so that the photo process causes electrons to arrive at the scanned surface. This results in the potential of the photoconductive surface adjacent to the collector electrode being operated negatively with respect to the equilibrium potential. Thus, elemental areas of the scanned surface are charged in a positive direction towards the equilibrium potential thereby minimizing redistribution of electrons. This solution to the problem of redistribution of electrons on the surface of the photoconductive layer has the disadvantage in that great loss of sensitivity results when the polarity of the photoconduction process is such as to deliver electrons

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to the surface scanned by the electron beam, particularly when selenium is employed as a photoconductor. On the other hand, if the polarity of the photoconduction process is such as to withdraw electrons from the surface scanned by the electron beam, the equilibrium potential of the photo sensitive surface becomes more positive with respect to the equilibrium potential, increasing the seriousness of the effect of redistribution of electrons.

One present type of camera tube which is generally referred to as the "Vidicon," incorporates a very low velocity electron beam to charge scanned areas of a photoconductive surface in a negative direction towards the potential of the source of the electrons of the beam. This enables the polarity of the photoconduction process to be oriented so as to withdraw electrons from the surface scanned by the electron beam, thereby retaining the sensitivity of the photoconductive process and at the same time operating the collector electrode at a potential that is considerably more positive than the equilibrium potential so as to attract secondary electrons away from the surface with the concomitant minimizing of the redistribution of electrons. The principal disadvantage of this type of tube is that its operation requires the use of a long axial magnetic field to direct the low velocity electron beam. An axial magnetic field required by a tube of this type considerably restricts the size of its image area and, in addition, requires the use of solenoids, such use introducing a number of limitations in the practical utility of the tube.

The camera tube of the present invention employs a photoconductive layer with a collector electrode disposed adjacent to one surface thereof, with means for scanning this surface with a high velocity electron beam of elemental cross sectional area, and means for directing high velocity flood electrons uniformly over the area of this surface. A transparent conductive coating is disposed on the surface opposite to the scanned surface of the photoconductive layer; this conductive coating being maintained at a fixed potential. A light image is focused through this transparent conductive coating on the photoconductive layer to initiate a photoconductive process which charges elemental areas of the scanned surface in a positive direction. The density of high velocity flood electrons is adjusted so that the scanned surface is charged at a faster rate in a negative direction by the flood electrons than the rate at which the photoconductive process charges it in a positive direction. Thus, an electrical signal, representative of the light image, is produced by the current to the collector electrode when the surface of the photoconductive layer is scanned by the electron beam to charge the scanned areas to the equilibrium potential in a positive direction.

The disclosed invention enables the polarity of the photoconductive process to be oriented so that electric charge is conducted through the photoconductive layer in the form of holes, thereby obtaining maximum sensitivity of the process. Also, since the photoconductive surface is scanned by a high velocity electron beam of elemental cross sectional area, there is no need to use an axial magnetic field to direct the beam as is required for low velocity beams. In addition, the electrical output signal is produced by charging scanned areas in a positive direction to the equilibrium potential, thus tending to minimize redistribution of the secondary electrons.

An alternate embodiment of the present invention is adapted to produce an electrical signal from an X-ray image, in which case it comprises a camera tube of the type described above including a fluoroscopic screen disposed contiguous to the surface of the photoconductive layer on which a visual image is focused. The X-ray embodiment of the present invention does not employ a photoemissive surface as is done by numerous devices

of this type, hence, there is no need to sensitize the photoconductive layer by exposing it to cesium vapor.

The use of cesium vapor for sensitizing purposes, necessitates the use of a thin aluminum coating over the fluoroscopic screen in order that there be no random reflections of light within the tube to cause extraneous excitations of the photosensitive surface. The use of the aluminum coatings for this purpose is included in an article entitled, "Electronic Intensification of Fluoroscopic Images," by M. C. Teves and T. Tol, which appears on pages 33 to 43 in Philips Technical Review for August 1952, published by Philips Research Laboratories, Eindhoven, Netherlands. The manner by which this embodiment of the present invention may be incorporated in an X-ray image intensifier system is described in a copending application for patent, by S. Hansen, filed June 30, 1945, Serial No. 365,161, now Patent No. 2,775,719, issued December 25, 1956, and entitled, "An X-Ray Image Intensifier System." This tube incorporates all the advantages attributable to the prior embodiment and, in addition, is capable of producing an electrical signal representative of an X-ray image which may be readily converted into a visual presentation that may be viewed by a radiologist without prior dark adaptation as required by numerous prior art X-ray systems. In addition, there is no limitation on the size or place of the visual presentation. Hence, the radiologist need not be exposed to harmful X-rays for long periods of time.

It is therefore an object of this invention to provide a method for minimizing the effect of redistribution of electrons on the surface of a photoconductive layer of a television type camera tube.

Another object of this invention is to provide an electronic camera tube incorporating high energy flood electrons directed uniformly over the area of one surface of a photoconductive layer to enable a photoconductive process to be used whereby electric charge is conducted through the layer in the form of holes.

Still another object of this invention is to provide an electronic camera tube incorporating a photoconductive process whereby electric charge is conducted through a photoconductive layer in the form of holes and means for scanning the surface of the photoconductive layer with a high velocity electron beam of elemental cross sectional area to produce an electrical signal representative of the charges thereon.

A further object of this invention is to provide an electronic camera tube incorporating a photoconductive process wherein electrons are conducted away from the surface of a photoconductive layer scanned by a high velocity electron beam of elemental cross sectional area towards the opposite surface of the layer which is in contact with a transparent conductive coating maintained at a fixed potential and on which a light image is focused.

A still further object of this invention is to provide an electronic camera tube particularly adapted to producing an electrical signal representative of an X-ray image.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of examples. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Fig. 1 is a diagrammatic sectional view of an embodiment of the invention with associated circuitry;

Fig. 2 is a diagrammatic sectional view of a modification of the embodiment shown in Fig. 1 particularly adapted for X-rays; and

Figs. 3 through 8 are explanatory diagrams relating to

the operation of the embodiments shown in Figs. 1 and 2.

Referring to Fig. 1, the camera tube of the present invention comprises an evacuated envelope 10, which in its left portion, as viewed in the figure, has an electron writing gun 12 for producing a high velocity electron beam of elemental cross sectional area, appropriate for deflecting means 14 for this electron beam, and a flood gun 16 for producing a broad beam of high velocity electrons. A collector electrode 13 and a target electrode 15 are disposed in the right portion of envelope 10, as shown in the figure.

The electron gun 12 consists of a conventional heater element 17 connected by means of conductors 18 to a source of filament potential 20, a button type cathode 22, an intensity grid 24 and beam-forming and accelerating electrodes 26, 28 and 30. The cathode 22 is connected to heater element 17 which is, in turn, connected over a lead 31 to a tap on a source of potential 32, the positive terminal of which is connected to ground, for maintaining the potential of cathode 22 at a potential of the order of -1000 volts with respect to ground. Intensity grid 24 is maintained at a potential of from 0 to 50 volts negative with respect to the potential of cathode 22 by a connection through a variable potential source 34 to cathode 22. The intensity of the electron beam produced by electron gun 12, of course, is determined by the extent to which intensity grid 24 is biased with respect to cathode 22.

Electrode 30 is connected to accelerating electrode 26 which is maintained at ground potential by a connection over a lead 36 to ground. Electrode 28 is normally maintained at a potential of the order of 250 volts positive with respect to the potential of cathode 22 or of the order of -750 volts with respect to ground. Accordingly, electrode 28 is maintained at a potential of the order of -750 volts with respect to ground by a connection to the negative terminal of an appropriate potential source 38 which has its positive terminal connected to ground. The operation and construction of an electron gun structure of the type described is well known in the art and therefore needs no additional description.

Deflecting means 14, disposed axially about the electron beam as it emerges from the electron gun 12, comprises vertical deflection plates 41, 42 and horizontal deflection plates 43, 44 which are shielded from each other by an electrode 45 disposed between vertical plates 41, 42 and horizontal plates 43, 44. Electrode 45 is maintained at the same potential as electrode 30 by means of a suitable connection thereto. While electrostatic deflecting means are illustrated in the figure, it is to be understood that magnetic beam deflection coils may also be used, in which case the horizontal and vertical deflection plates would be replaced with appropriate magnetic deflection coils. Vertical and horizontal plates 41, 42 and 43, 44 are maintained at ground potential by connections to ground over leads 46, 47 through isolation resistors 48, 49 and 50, 51, respectively.

Capacitors 53, 54 and 55, 56 couple vertical deflection plates 41, 42 and horizontal deflection plates 43, 44, respectively, to suitable sources of balanced scanning voltages, the circuitry for which is not illustrated in the figure. The disclosed tube is in no way restricted to a particular mode of scanning and, since suitable scanning circuits are known in the art, no detailed description of any scanning circuit is presented.

Flood gun 16 includes a conventional heater element 58 connected through a pair of conductors 59 to a source 61 of filament potential, a cathode 62 connected to heater element 58, a beam-forming electrode 63, and an accelerating electrode 64. Electrode 64 extends over electrode 63 and cathode 62 in order to shield flood gun 16 from electron gun 12 and deflecting means 14. Beam-forming electrode 63 is connected over a lead 66 to the negative terminal of a source 67 of variable direct-cur-

rent potential, the positive terminal of which is connected to cathode 62. Source 67 provides a potential that is variable from 0 to 200 volts. Flood gun cathode 62 is maintained at a potential that is dependent on the secondary electron emission characteristics of the surface of target electrode 15 that is exposed to the action of the flood electrons. More particularly, cathode 62 is maintained at a potential that is sufficiently negative with respect to the potential of this exposed surface to cause the electrons to impinge on the surface at a high velocity such that fewer secondary electrons are released from the surface than electrons incident on the surface. This potential may be of the order of -5000 volts with respect to ground and is impressed on cathode 62 by means of a connection to the negative terminal of potential source 32. Accelerating electrode 64 is maintained at ground potential by a suitable connection thereto.

Electrode 69 provides a suitable drift space between flood gun 16 and collector electrode 13 and may comprise any suitable conductive material disposed on the inner surface of evacuated envelope 10 between the flood gun 16 and deflecting means 14 on the one extremity and collector electrode 13 on the other. Electrode 69 is maintained at ground potential by means of a suitable connection over a lead 71 to ground.

As previously mentioned, target electrode 15 and collector electrode 13 are disposed in the right portion of evacuated envelope 10 opposite the electron guns, as viewed in Figure 1. Target electrode 15 comprises a transparent member formed by a thin glass plate 72 having a transparent conductive coating 73 such as, for example, tin oxide, disposed on the side exposed to electron gun 12 and flood gun 16. A conventional method of providing a transparent conductive coating of tin oxide on glass, is to expose the surface of the glass to stannous chloride vapors in the presence of oxygen. A photoconductive layer 74 is then applied to the conductive coating 73 of the transparent member. This may be accomplished, for example, by evaporating a thin layer of selenium on the conductive coating 73 while maintaining the temperature of the target electrode 15 less than 60° C. so that the selenium will be deposited in its red vitreous form. The thickness of photoconductive layer 74 is of the order of from 5 to 10 microns. In the tube of the present invention, one surface of photoconductive layer 74 is exposed to the electron beam produced by electron gun 12 and the high velocity flood electrons emanating from flood gun 16 while the other surface is in actual contact with the transparent conductive coating 73. This transparent conductive coating 73 is maintained at potential of the order of +50 volts with respect to ground by a connection to the positive terminal of a potential source 76, which has its negative terminal connected to ground.

The collector electrode 13, as shown in Fig. 1, is an annularly shaped metallic element having a shape that corresponds approximately to the periphery of target electrode 15. Collector electrode 13 is disposed adjacent to and in register with target electrode 15 and has a depth that is dependent on the area of the photoconductive surface provided by electrode 15. The quiescent potential of collector electrode 13 is maintained at ground potential by a connection through a resistor 77 to ground. Current variations through resistor 77 provide an output signal which is available at a terminal 78. This output signal may contain relatively high frequencies, hence, an annularly shaped collector electrode 13 is employed to minimize the capacity to target electrode 15 so as not to provide a shunt path for the signal around resistor 77 to ground.

Reference is made to explanatory Figs. 3 and 4 for a description of the secondary electron emission phenomenon that pertains to the disclosed tubes. Referring particularly to Fig. 3, there is shown a representative secondary electron emission characteristic 90 for the photo-

conductive layer 74 in the tube of the present invention. Characteristic 90 comprises a line representing values of the true secondary electron emission ratio versus the velocity in volts at which electrons are incident on the surface of layer 74. By true secondary electron emission ratio is meant the ratio of the actual number of secondary electrons. At very low velocities, large portions of the incident electrons will be repelled, hence, there will be very few true secondary electrons released. The number of secondary electrons increases almost linearly as the electron velocity is increased until a velocity of the order of 75 volts is reached at a point 91 where the number of secondary electrons released is equal to the number of incident primary electrons. This velocity in volts may be referred to as the "first crossover." As the velocity of the incident electrons is increased beyond the first crossover, more and more secondary electrons are emitted for each incident primary electron until the ratio of secondary electrons to primary electrons is approximately three. Increasing the velocity of the incident primary electrons still further causes them to penetrate deeper into the material of layer 74 so that the prospective secondary electrons released from their molecular bonds find it increasingly difficult to get free from the molecular matrix comprising the material of layer 74. Finally, a point 92 is reached where the number of secondary electrons released is again equal to the number of incident primary electrons. This point may be referred to as the "second crossover" point.

Referring now to Fig. 4, there is shown an effective secondary electron emission characteristic 100 for the photoconductive material composing layer 74 when a collector grid, maintained at a potential E_c , is disposed adjacent to its surface. By effective secondary electrons is meant true secondary electrons released by incident primary electrons plus any primary electrons repelled from the surface of layer 74. The effect of adding the repelled primary electrons to the true secondary electrons is to cause the secondary electron emission ratio to commence decreasing from unity at low electron velocities until all the primary electrons impinge on the surface of layer 74 at which point characteristic 100 coincides with the starting point of characteristic 90. A portion 101 of characteristic 100 illustrates the effect of combining repelled primary electrons with the true secondary electrons.

The effect of disposing a collector grid, maintained at a potential E_c adjacent to the surface of layer 74, is to cause the secondary electron emission characteristic to follow a path indicated by a portion 102. This is because the incident primary electrons release secondary electrons which are attracted to the more positive element. Since the electrons constitute negative charges, the potential of the collector grid obviously controls the extent to which the surface of layer 74 may be charged in a positive direction. As illustrated in Fig. 4, there exists an equilibrium potential at a point 103 where the portion 102 intersects with the unity secondary electron emission value. When the potential of the surface of layer 74 is negative with respect to the equilibrium potential, the secondary electron emission ratio is greater than unity so more electrons leave the surface than are coincident thereon, thereby charging the surface in a positive direction towards the equilibrium potential. On the other hand, when the potential of the surface of layer 74 is positive with respect to the equilibrium potential, the secondary electron emission ratio is less than unity so a lesser number of electrons leave the surface than are incident thereon, thereby charging the surface in a negative direction towards the equilibrium potential.

Referring again to Fig. 1, the camera tube of the present invention operates by first focusing a light image on target electrode 15, particularly on the surface of the photoconductive layer 74 in contact with the transparent conductive coating 73. The effect of the light on the

surface of photoconductive layer 74 is to release electrons from each elemental area thereof in proportion to the intensity of the light on the elemental area. The electrons released in this manner are conducted away from the photoconductive layer 74 by transparent conductive coating 73 because of the potential gradient existing in this region as hereinafter explained. When an electron is released and conducted away from the photoconductive layer, there is left what is generally termed as a "hole." A hole is a region where there is a deficiency of electrons which, in essence, is a positive charge.

Simultaneously with the above process, flood gun 16 directs high velocity electrons uniformly over the area of the surface of photoconductive layer 74 exposed to the electron guns to charge the surface in a negative direction and the electron beam produced by electron gun 12 is caused to scan the area of this surface by deflecting means 14. The effect of scanning an elemental area of the surface of photoconductive layer 74 with the electron beam is to charge the elemental area to the equilibrium potential that is several volts positive with respect to the potential of collector electrode 13. During normal operation of the tube, the surface of photoconductive layer 74 scanned by the electron beam will be periodically charged to this equilibrium potential.

Since the quiescent potential of collector electrode 13 is ground and the potential of transparent conductive coating 73 is at +50 volts with respect to ground, it is thus seen that a potential of 50 volts is produced between the two surfaces of photoconductive layer 74, the surface on which the light image is focused being the more positive. The effect of having a potential gradient across layer 74 is to cause the holes produced by the light image to migrate towards the more negative surface. The manner in which a hole is conducted through a photoconductive material by a potential gradient is that electrons from the more negative regions are attracted into the hole by the potential gradient once it is produced by light incident on the more positive surface. Upon filling the hole, the electrons leaving the more negative regions create a new hole which is again filled by electrons from the more negative regions with respect to the new hole due to the potential gradient. Thus, the hole migrates in this manner towards the more negative surface of photoconductive layer 74. The effect of this photoconduction of the holes through layer 74 is to produce a positive charge on each elemental area of the more negative surface that is proportional to the light intensity on the more positive surface opposite the elemental area.

From the foregoing explanation, it follows that the transfer of electric charge through the layer 74 is accomplished by the migration of holes through the photoconductive material. Since photoconductive materials are generally very poor conductors of electrons and relatively good conductors of holes, it is a decided advantage to operate the polarity of the potential gradient across the photoconductive layer 74 such that charge is transferred in the form of holes.

As previously described, the effect of periodically scanning the more negative surface of layer 74 with the writing beam, produced by gun 12, is to charge this surface to the aforementioned equilibrium potential. The electron velocity of the writing beam is adjusted so that more secondary electrons are released from a scanned elemental area than primary electrons incident on the elemental area. These secondary electrons will be attracted in the direction of the highest positive potential gradient. Since the holes conducted to the scanned surface of layer 74 are equivalent to a positive charge, adjacent areas of an elemental area scanned by the electron beam will be more positive than the equilibrium potential. Thus, in order to charge an elemental area to the equilibrium potential in the absence of the high energy

biasing electrons from flood gun 16, it would be necessary for the electron beam to charge the elemental area in a negative direction. To accomplish this by secondary electron emission would entail having secondary electrons attracted back to the elemental area. Since areas adjacent to the elemental area being charged to the equilibrium potential will generally be more positive than the elemental area being charged, many of the secondary electrons will be attracted to these adjacent areas rather than being attracted back to the elemental area from whence they were released. This spreading out of the secondary electrons is known as the redistribution of electrons effect.

To explain more clearly the above phenomenon, reference is made to Fig. 5 which shows the portion 102 of the secondary electron emission characteristic 100 of Fig. 4. The potential of the scanned surface of layer 74 will be returned to the equilibrium potential corresponding to the point 103 by the action of the electron scanning beam. Therefore, since the photoconductive process charges the scanned surface in a positive direction, elemental areas of the surface will be charged within the limits indicated by a range 104 in Fig. 5. Any potential in range 104 is positive with respect to the equilibrium potential corresponding to point 103. Hence, returning the areas charged by the photoconductive process to the equilibrium potentials involves charging the areas in a negative direction by secondary electron emission means which, as hereinbefore explained, has the tendency of causing redistribution of the secondary electrons.

On the other hand, if the scanned elemental area were charged in a positive direction towards the equilibrium potential, secondary electrons would tend to be attracted towards collector electrode 13 to effect the charging and, in addition, the scanned elemental area would now be more positive than the surrounding areas and thus will tend to prevent secondary electrons from spreading to the surrounding areas thus minimizing the redistribution of electrons.

Charging of the scanned surface of photoconductive layer 74 by the electron beam, in a positive direction to minimize the redistribution of electrons effect, is accomplished by directing high velocity electrons from flood gun 16 uniformly over the area of the scanned surface. The cathode 62 of flood gun 16 is maintained at a sufficiently negative potential with respect to the potentials of the scanned surface of photoconductive layer 74 so that the flood electrons will penetrate into layer 74 to the extent that fewer secondary electrons are released from a bombarded area than primary electrons incident thereon. That is, the flood electrons have a velocity in excess of the second crossover velocity described in connection with Fig. 3. Thus, the high velocity electrons from flood gun 16 will accumulate and charge the scanned surface of layer 74 in a negative direction at a uniform rate. This phenomenon is illustrated in Fig. 6. Referring to this figure, there is shown the portion 102 of the secondary electron emission characteristic 100 of Fig. 4 wherein point 103 corresponds to the aforementioned equilibrium potential. The flood electrons act to charge the scanned surface in a negative direction through a range 105 as indicated in Fig. 6. An appropriate density of these flood electrons is used so that the uniform rate at which an area of the scanned surface is charged in a negative direction exceeds the rate at which the area might be charged in a positive direction by photoconduction. Therefore, the net effect of charging an area with high velocity flood electrons and by photoconduction is to charge the area in a negative direction at a linear rate proportional to the light intensity initiating the photoconduction.

Figs. 7 and 8 illustrate more clearly the foregoing charging phenomena. Fig. 7 illustrates again the portion 102 of the secondary electron emission characteristic 100 of Fig. 4 wherein point 103, as before, corresponds to the equilibrium potential. The combined effect of the charg-

ing by the flood electrons and by the photoconduction process is to charge elemental areas of the scanned surface to potentials within the limits indicated by a range 106 of potentials having a magnitude ΔE . It is generally preferable to restrict range 106 to linear portions of the secondary electron emission characteristic so as to obtain an output voltage from an elemental area that is directly proportional to the light intensity corresponding to the elemental area.

Fig. 8 illustrates typical charging curves and the manner in which charging by the flood electrons and the photoconduction process is combined. In Fig. 8, the range 106 of potentials having a magnitude ΔE is expanded along the vertical axis having the equilibrium potential as a reference and time is indicated along the horizontal axis, the interval at which elemental areas of the surface of layer 74 are periodically charged to the equilibrium potential being designated as Δt . Lines 107 indicate voltage to which the high velocity flood electrons charge the surface of layer 74 versus time. Lines 108, 109 indicate the voltages to which the photoconduction process charges elemental areas of the surface of layer 74 versus time for a low level of light intensity and for a high level of light intensity, respectively. Lines 110, 111 represent the composite voltages represented by lines 107, 108 and 107, 109 to which elemental areas of the surface of layer 74 may be charged versus time for the low and the high level of light intensity, respectively. Thus, a low level of light intensity has little effect in counteracting the charging by the flood electrons whereas a high level of light intensity may almost completely counteract the charging by the flood electrons.

From the above, it follows that the scanned surface will be charged to varying potentials that are slightly positive with respect to the potentials of collector electrode 13, but negative with respect to the equilibrium potential. The areas that correspond to dark portions of the light image are more negative than areas corresponding to portions of the light image where the light is more intense. An electrical signal corresponding to the light image is then produced by scanning the photoconductive layer 74 with the electron beam produced by electron gun 12. This beam in cooperation with collector electrode 13 charges each scanned area of layer 74 in a positive direction to the equilibrium potential. Simultaneously with the scanning of the photoconductive layer 74 with the electron beam, collector electrode 13 will collect the excess electrons produced in the charging process. Since the current in the electron beam is maintained substantially constant, the number of electrons that are collected during the interval that the electron beam is scanning a certain area will be indicative of the original charge on the scanned area. That is, more electrons will be collected during the interval that the electron beam is scanning the more negative areas as the charging is always in a positive direction. The electrons collected by collector electrode 13 flow through the resistor 77 to ground to produce an electrical output signal representative of the intensity of the light image focused on photoconductive layer 74.

An alternate embodiment of the present invention especially adapted to produce an electrical signal representative of an X-ray image is illustrated in Fig. 2. This embodiment is identical to that in Fig. 1 except for modifications in the collector electrode 13 and target electrode 15. In view of the above, only the collector and target electrodes are illustrated in Fig. 2. Referring to Fig. 2, there is illustrated a sectional view of the right portion of envelope 10 showing a collector grid 123 disposed contiguous to a modified target electrode 120.

Target electrode 120 comprises a thin sheet of glass 121 or other transparent dielectric having a transparent conductive layer 73 and a photoconductive layer 74 disposed on one surface thereof in the same manner as in the tube of Fig. 1. A fluoroscopic X-ray screen 122 is disposed

on the opposite surface of glass sheet 121. The fluoroscopic X-ray screen 122 may include, for example, zinc sulphide activated with silver to obtain a blue fluorescence when excited by X-rays. X-ray screens per se of this type are known in the art, and need no further description of the methods for making such screens. The sheet of glass 121 is made thin in order to minimize diffusion of the light between the X-ray screen and the photoconductive layer 74, a representative thickness being of the order of 1 millimeter or less.

A collector grid 123 is disposed contiguous to and in register with target electrode 120. In this embodiment of the invention, the collector comprises a conventional metallic mesh rather than the annularly shaped electrode shown in connection with the embodiment illustrated in Fig. 1. The particular advantage of collector grid 123 resides in the fact that it has more control over the potential predominating at the surface of photoconductive layer 74. At the same time, however, the capacitance to target electrode 120 is considerably increased which would decrease the frequency response across resistor 77. An electrical signal representative of an X-ray image, however, would presumably have a predominance of lower frequency signals so the effect of the increased capacitance would not be too serious.

The operation of the embodiment of the tube shown in Fig. 2, is commenced by projecting an X-ray image through a body 125 on to the fluoroscopic screen 122 where the X-rays are converted to light, which initiates the photoconductive process. The remaining phases of operation of the tube are identical to the corresponding phases of operation of the tube illustrated in Fig. 1 and, therefore, need no additional description.

What is claimed as new is:

1. An electronic camera tube for converting a light image into corresponding electrical indications, said tube comprising means for generating an electron beam of elemental cross sectional area; a target element including a transparent conductive pane and a photoconductive layer with secondary electron emission characteristics having a first surface receptive to the light image in contact with said pane and a second surface exposed to said electron beam; means for periodically scanning said second surface with said electron beam to liberate more secondary electrons than beam electrons incident thereon; means for collecting said secondary electrons at a first collector potential level to charge each scanned elemental area of said second surface substantially to said first potential level; means for directing high energy electrons uniformly over the area of said second surface to charge each elemental area thereof in a negative direction at a predetermined rate; means for focusing a light image on said first surface for releasing electrons from each elemental area thereof in proportion to the light intensity thereon; and means for maintaining said conductive pane at a second potential level positive with respect to said first potential level for removing the released electrons from said first surface to create holes whereby said holes migrate to said second surface to charge each elemental area thereof in a positive direction at a rate less than said predetermined rate and proportional to the light intensity on the corresponding elemental area of said first surface, the secondary electrons collected at said first potential level from said second surface constituting an electrical signal representative of said light image.
2. The electronic camera tube as defined in claim 1 including a fluoroscopic screen disposed contiguous to and in register with said transparent conductive pane of said target element for converting X-rays into light.
3. The electronic camera tube as defined in claim 1 wherein said thin photoconductive layer is composed of the red vitreous form of selenium.
4. An electronic camera tube for converting a light image into corresponding electrical indications, said tube comprising means for generating an electron beam of

elemental cross sectional area; a target element including a thin glass pane, a transparent conductive coating on one side thereof, and a photoconductive layer having a first surface receptive to the light image in contact with said conductive coating and a second surface exposed to said electron beam; means for periodically scanning said second surface with said electron beam to liberate more secondary electrons than beam electrons incident thereon; means for collecting said secondary electrons at a first collector potential level to charge scanned areas of said second surface substantially to said first potential level; means for directing high energy electrons uniformly over the area of said second surface to charge each elemental area thereof in a negative direction at a predetermined rate; means for focusing a light image on said first surface for releasing electrons from their molecular bonds within each elemental area thereof in proportion to the light intensity thereon; and means for maintaining said conductive coating at a second potential level positive with respect to said first potential level for removing electrons from said first surface to create holes whereby said holes migrate to said second surface to charge each elemental area thereof in a positive direction at a rate less than said predetermined rate and proportional to the light intensity on the corresponding elemental area of said first surface, the secondary electrons collected from said second surface at said first potential level being indicative of the light intensity of the image corresponding to the elemental area of said second surface being scanned by said beam.

5. An electronic camera tube for converting an X-ray image into a corresponding electrical indications, said tube comprising means for generating an electron beam of elemental cross sectional area; a target element including a thin glass pane, a fluoroscopic screen disposed on one side thereof for converting the X-ray image into a light image, a transparent conductive coating disposed on the other side thereof, and a photoconductive layer having first and second surfaces, said first surface being in contact with said conductive coating and said second surface being exposed to said electron beam; means for periodically scanning said second surface with said electron beam to liberate more secondary electrons than beam electrons incident thereon; means for collecting said secondary electrons at a first collector quiescent potential level to charge scanned areas of said second surface substantially to said first potential level; means for directing high energy electrons uniformly over the area of said second surface to charge each elemental area thereof in a negative direc-

tion at a predetermined rate; and means for maintaining said conductive coating at a second potential level positive with respect to said first potential level for producing a potential gradient across said photoconductive layer whereby the light intensity of each elemental area of the light image releases electrons from their molecular bonds in corresponding elemental areas of said first surface in proportion to the light intensity thereon and said potential gradient removes the released electrons to create holes which migrate to said second surface to charge each elemental area thereof in a positive direction at a rate less than said predetermined rate and proportional to the light intensity on the corresponding elemental area of said first surface, the secondary electrons collected at said first potential level being indicative of the light intensity of the image corresponding to the elemental area of said second surface being scanned by said beam.

6. In a cathode ray device, a target electrode including a transparent member having a conductive surface and a photoconductive layer disposed on said surface, said photoconductive layer being receptive to a light image projected through said member on said surface whereby electric charge is liberated from said photoconductive layer in proportion to the light intensity thereon; means disposed adjacent said target electrode for collecting secondary electrons from said photoconductive layer at a predetermined collector potential level; means for generating a beam of high velocity electrons; means for sequentially directing said beam to bombard said photoconductive layer to charge bombarded areas thereof substantially to said predetermined potential level; means for uniformly bombarding said photoconductive layer with additional high velocity electrons to charge the bombarded areas thereof in a negative direction at a uniform rate; means for maintaining said conductive surface at a potential positive with respect to said predetermined potential level, whereby said electric charge is conveyed through said photoconductive layer in the form of holes thereby to produce a charge replica of said light image, the potentials constituting said charge replica being negative with respect to said predetermined potential level.

References Cited in the file of this patent

UNITED STATES PATENTS

2,339,662	Teal	Jan. 18, 1944
2,345,282	Morton et al.	Mar. 28, 1944
2,588,254	Lark-Horowitz et al.	Mar. 4, 1952
2,614,235	Forgue	Oct. 14, 1952