March 13, 1951 C. H. TOWNES 2,544,754

ELECTRON CAMERA TUBE

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FIG. 1

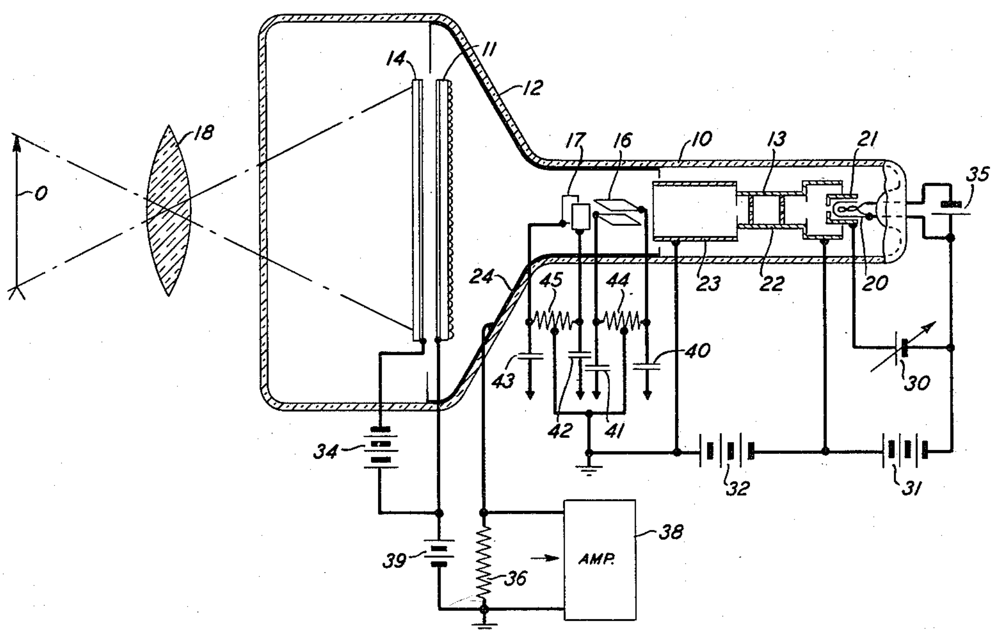


FIG. 2

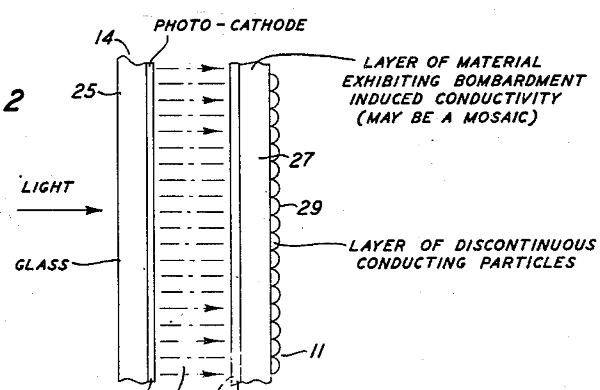
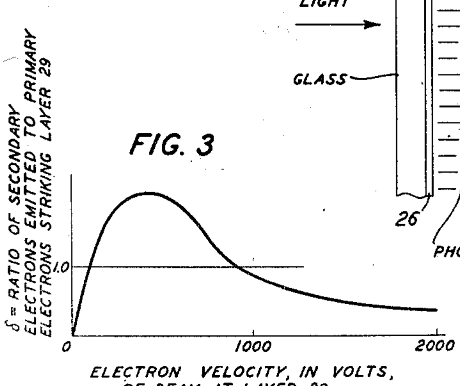


FIG. 3



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ELECTRON CAMERA TUBE

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7 Claims. (Cl. 250—153)

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This invention relates to electro-optical devices and more particularly to electron camera tubes for television.

It is an object of this invention to utilize in electron camera tubes materials exhibiting the property of electron bombardment induced conductivity.

It is another object of this invention to improve the response of certain types of electron camera tubes.

In the copending applications of D. E. Wooldridge, Serial No. 747,888, filed May 14, 1947, which is now U. S. Patent #2,537,388, granted January 9, 1951, and K. G. McKay, Serial No. 789,667, filed December 4, 1947, there are disclosed various materials which exhibit the property known as bombardment induced conductivity. Each of these materials (such as, for example, diamond, zinc sulphide, magnesium oxide, silicon carbide and stibnite) is normally an insulator but when it is struck by electrons (or other particles, such as alpha or beta particles, for example), it becomes conducting if at the time an electric field exists between opposite surfaces of the insulator. The bombarding particles penetrate the insulator, causing a disruptive separation of the positive and negative charges specific to the atoms which are effected by the bombarding particles. These charges are drawn toward the electrodes producing the electric field and this motion of charges constitutes a conduction current which is in many cases greatly in excess of the current of the bombarding particles.

Diamond is a favored solid insulator for this work (although other materials such as, for example, others listed in the Wooldridge and McKay applications can also be used) because it can easily be obtained without sufficient impurities or imperfections to affect its high insulation resistance, or its conducting properties under bombardment. The carbon atoms therein consist each of a nucleus exhibiting fixed units of positive charge to which two electrons are tightly bound. This core is surrounded by four valence electrons. The carbon atoms are held together by "electron pair bonds" between adjacent atoms. The insulation resistance is high because the electron bonds are very tight. As a result of this tightness, very few electrons are displaced from their bonds by thermal agitation. This is not the case in, for example, metals, where a large number of electrons are continuously being displaced by thermal agitation and are relatively free to wander through the

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metal, this, under normal conditions, constituting the usual current in a metallic conducting medium.

When electron bombardment removes a valence electron from its bonds in an insulating target, producing a deficiency of one electron in the atomic structure immediately affected, this localized electron deficiency is called a "hole." Under an applied electric field, the arrangement of the electrons is changed, and the location of any given hole will change. As a consequence, the hole can be conveniently regarded as a positive particle which is free to move under the influence of the field. Similarly, the electron freed from the bond in question constitutes a negative particle which is free to move under the influence of the electric field. If there is no applied field, any free electron or positive hole moves in accordance with thermal agitation and consequently has a completely random motion. Under an applied electric field, there is a directional motion superimposed on the random one. The order of mobility of the electrons in diamond is of the order of 1,000 centimeters per second for a field of one volt per centimeter. For a field of 10^4 volts per centimeter the velocity therefore is 10^7 centimeters per second. For a diamond crystal one millimeter thick, the transit time therefore is 10^{-8} seconds. The mobility of the electrons is affected by the number of "traps," that is, the presence of foreign atoms or imperfections in the crystal. If an electron gets into a trap, it takes a greater or less amount of time to get out, depending upon the thermal energy required. Further information on traps and other characteristics of diamond crystals are given in the Wooldridge and McKay applications referred to above.

In accordance with the present invention, there is provided an electron camera tube including an electron target embodying material which exhibits the property of electron bombardment induced conductivity. Diamond is the preferred material for reasons given above. The camera tube includes a two-sided mosaic target comprising a mosaic layer of diamond or other crystals exhibiting the property of electron bombardment induced conductivity. The diamond layer is coated on one side with a thin conducting layer and on the other with a multiplicity of islands of conducting material. The thin conducting layer is struck by high velocity electrons modulated by light from an object or field of view while the conducting islands are scanned by a high velocity electron beam.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof in which:

Fig. 1 is a schematic representation of a cathode ray tube of this invention and certain of its associated circuits and auxiliary equipment;

Fig. 2 is a schematic view showing, in greatly enlarged form, a portion of the target and of the photoelectric cathode of the tube shown in Fig. 1; and

Fig. 3 is a graphical representation to aid in explaining the invention.

Referring more particularly to the drawing, Fig. 1 shows, by way of example to illustrate the invention, a cathode ray television transmitter tube 10 employing a two-sided mosaic target 11 containing material exhibiting the property of electron bombardment induced conductivity. The tube 10 comprises an evacuated container 12 enclosing the mosaic target 11, an electron gun 13 for generating, focussing and accelerating a beam of high velocity electrons toward this target, a photocathode 14 on the side of the target 11 remote from the electron gun 13, and two sets of electrostatic deflecting plates 16 and 17 for causing the beam of electrons to scan every elemental area in turn of a field of view on the mosaic target 11. Radiations from an object or field of view O are applied to the photocathode 14 by means of any suitable optical system represented schematically by the single lens 18.

The electron gun 13 preferably comprises a cathode 20, a control electrode or member 21, a first anode member 22 and a second and final anode comprising a cylindrical member 23. A coating 24 on the inside walls of the envelope 12 extending from the region of the cylinder 23 to the region of a mosaic target 11 serves to collect electrons from the target. The conducting coating 24 serves as a collector for electrons from the target 11.

Referring now to Fig. 2 for details of the elements 11 and 14, the member 14 includes a semitransparent coating 26 of photoelectric material on a suitable transparent support 25 such, for example, as glass. If desired, the coating 26 may be applied to the end wall of the cathode ray tube. Separated from the member 14 by a small space is the target 11 which includes a layer 27 of material exhibiting the property of electron bombardment induced conductivity. Such a material may be a single diamond sheet or, more practically, it can comprise a composite structure formed of a layer (preferably one particle thick) of diamond chips or diamond dust. Alternatively, the layer 27 can be of any other suitable material exhibiting this desired property. The layer 27 is coated on the side nearer the photocathode 14 with a very thin conducting coating 28 of gold or other suitable material deposited in a continuous layer. On the other side of the layer 27 may be deposited a continuous layer 29 comprising a number of small islands of a suitable conducting material such as gold, for example, the islands being insulated from one another. These islands can be produced, for example, by covering the layer 27 with a fine uniform mesh of wire, evaporating a suitable conducting material over the surface, and then removing the wire mesh. For some types of layers 27, a layer 29 thereon is not necessary although the beam velocity may have to be different from that which would be necessary if a layer 29 were present (due to the different secondary emitting characteristics of the materials making up the layers 27 and 29).

A high potential is maintained between the members 14 and 11. By way of example, a source 34 of the order of 10,000 volts is connected between members 14 and 11 so that the conducting coating 28 of the member 11 is highly positive with respect to the member 14. If the members 14 and 11 are spaced apart by any great distance, any well-known electrostatic or electromagnetic focussing arrangement can be used to keep the photoelectrons in paths parallel to the axis of the tube 10.

The control electrode 21 is placed at any suitable negative potential with respect to the cathode 20 by means of an adjustable source 30; and the first anode 22 and the final anode 23 are placed at appropriate positive potentials with respect to the cathode 20 by means of the source 31 and the source 32. The first anode 22 is placed at an appropriate positive potential which is somewhere between the potential of the anode 23 and that of the cathode 20. The actual potentials applied to the various electrode members and their configurations and shapes are such that a beam of focussed, high velocity electrons strikes the target 11 at a velocity which produces a secondary emitting ratio δ for the layer 29 equal to unity. Any suitable source 35 can be utilized to heat the cathode 20. The negative terminal of the source 31 is connected to the cathode 20 and the positive terminal thereof is connected to the first anode 22. The negative terminal of the source 32 is connected to the positive terminal of the source 31 and the positive terminal of the source 32 is connected to ground. The metallic coating 24 is connected to ground through the signal output resistor 36. Exemplary values for the various potentials applied to the electron gun elements and to the target 11 will be given below.

Any suitable amplifier 38 is connected to the signal resistor 36 and the amplifier is in turn connected to the other elements of the television transmitter circuit which prepares the video signal for transmission to the receiving station.

The electron beam is deflected over a suitable field on the target 11 by means of appropriate potentials applied to the deflecting plates 16 and 17 by electrostatic sweep circuits (not shown). As examples of satisfactory sweep circuits, reference is made to Patent 2,178,464 issued October 31, 1939, to M. W. Baldwin, Jr., which discloses balanced electrostatic sweep circuits suitable for this purpose. Connections can be made from the balanced sweep circuit to the pairs of plates 16 and 17 by means of coupling condensers 40, 41, 42 and 43, respectively, of about one microfarad capacity each. Coupling resistances 44 and 45, of the order of many megohms each, are respectively connected across the pairs of plates 16 and 17. The mid-points of the resistances 44 and 45 are connected to the positive terminal of the source 32 so that the average of the potentials of the deflecting plates does not deviate more than slightly from the potentials of the anodes 23 and 24. This relationship is maintained to avoid changes in the sensitivity of the deflecting system and the consequent distortion of the image which would otherwise result. For a more complete description of the advantages of balanced sweep circuits for use with cathode ray television tubes, reference is made to the above-mentioned Baldwin patent and also to Patent 2,209,199 issued July 23, 1940, to Frank Gray.

The operation of the arrangement shown in

Fig. 1 is as follows, reference also being made to Fig. 2. Radiations from the object or field of view O are projected upon the photocathode 14 by means of the lens system 18. At the same time a high velocity beam of electrons is generated by the gun 13 and is deflected over a field of the mosaic target 11 corresponding to the area covered by the radiations from the object O on the electrode member 14, this scanning being made possible because of appropriate sweep potentials applied to the deflecting plates 16, 17. Initially the cathode 20 is placed at a potential of about 1,000 volts negative with respect to the electrode 23, the electrode 24 being at the same potential as the member 23 in the absence of current in the signal resistor 36. The electrode 22 is placed at a proper value, intermediate that of the member 20 and 23, to produce sharp focussing. An exemplary value for this potential is 300 volts. The source 33, of the order of 1,000 volts, places the potential of the metal layer 28 at a value of about 2,000 volts positive with respect to the cathode 20. Before electrons from the gun 13 strike the layer 29, it is at the same potential as the layer 28 (that is, at about 2,000 volts positive with respect to the cathode). Referring to Fig. 3, which is a graph of δ (ratio of number of secondary electrons emitted from the surface 29 to the number of primary electrons striking it) versus the electron velocity of the beam, in volts, at the surface 29, it is seen that when the electron velocity is 2,000 volts, δ is much less than 1.0. This means that, when the beam strikes the surface 29, electrons are accumulated on the surface 29, driving its potential in a negative direction. At about a potential of 100 volts negative with respect to ground (about 900 volts positive with respect to cathode potential, for example) an equilibrium will be reached with $\delta=1.0$. The exact value of this equilibrium potential of the surface 29 with respect to that of the electrode 23 (ground) can be adjusted by varying the voltages of the sources 32 and 31. At a potential of -100 volts for the surface 29, electrons are attracted to the collector 24. The potential of the coating 28 is thus about 1,100 volts positive with respect to the discontinuous coating 29 which is sufficient for obtaining electron bombardment induced conductivity. (The potential of the member 28 does not effect the focus of the beam because of the screening action of the target 11.) This equilibrium condition is stable since if the potential of the conducting coating 29 becomes more positive with respect to the cathode, the number of secondary electrons being emitted is decreased and this tends to make the potential of the coating 29 swing in a negative direction. Conversely, if the potential of the discontinuous coating 29 becomes more negative than this equilibrium potential, the number of secondary electrons is increased, tending to restore it to its original value. Under these conditions, when a light image from the object O falls on the photoelectric surface 26, the emitted photoelectrons from the various elemental areas of the surface 26 are accelerated to a very high velocity by the source 34, bombard the conducting surface 28 of the layer 27 and tend to make the various elemental areas of the layer 27 conducting by amounts determined by the light intensity of the corresponding elemental areas of the object. The bombardment induced current thereby initiated produces sudden changes in the potentials of the corresponding islands of the surface 29 on the opposite side of the layer 27. The next sweep of the electron beam from the gun 13 across these islands tends to restore their original equilibrium voltages and in this process the electron current from the surface 29 to the collecting electrode 24 is effected in the desired way to produce an output signal current. This current sets up a signal voltage across the resistor 36 and the voltage across this resistor is amplified by the amplifier 38 in a manner well known in the art. The video voltage thus amplified is then caused to modulate a carrier for transmission to a distant station by means well known. The tube of this invention is capable of a very large output current due to the feature of electron bombardment induced conductivity.

Various modifications can be made in the embodiment described above without departing from the spirit of the invention, the scope of which is indicated by the appended claims. The voltages given above are merely by way of example and can vary over a wide range depending on the type of electron gun structure, the spacing and arrangement of the various parts of the target structure with respect to the gun, and the material of the target.

What is claimed is:

1. An electron camera tube comprising a target for electrons including a thin, substantially continuous layer of an electrical insulator which has the property of becoming a conductor when bombarded with electrons, a conducting coating on one side of said layer, means for forming and directing to said coating image-modulated high velocity photoelectrons, and means for scanning the side of said target remote from said conducting coating with a beam of high velocity electrons.

2. An electron camera tube comprising an evacuated enclosure having therein a photocathode adapted to have applied thereto a light image, a target aligned with said photocathode, said target comprising a thin, substantially continuous layer of an electrical insulator which has the property of becoming a conductor when bombarded with electrons, a conducting coating on the side of said layer near said photocathode, a multiplicity of conducting islands on the side of said layer remote from said photocathode, and an electron gun positioned in said tube so that the electron beam produced thereby strikes the side of said target remote from the photocathode.

3. An electron camera tube target comprising a metal base member, a layer thereon of a material exhibiting the property of changing from an insulator to a conductor when bombarded with electrons, and a multiplicity of small conducting islands on the surface of said crystal layer remote from said base member.

4. An electron camera tube target comprising a metal base member, a layer thereon of a material exhibiting the property of changing from an insulator to a conductor when bombarded with electrons, and a multiplicity of small conducting islands on the surface of said crystal layer remote from said base member, said layer comprising a thin continuous sheet of said material.

5. An electron camera tube target comprising a metal base member, a crystal structure thereon of a material exhibiting the property of changing from an insulator to a conductor when bombarded with electrons, and a multiplicity of small conducting islands on the surface of said crystal layer remote from said base member, said layer

comprising a mosaic of small particles of said material, a single particle thick.

6. An electron camera tube target comprising a metal base member, a diamond layer thereon, and a multiplicity of small conducting islands on the surface of said diamond layer remote from said base member.

7. In an electron camera tube, an insulating member exhibiting the property of electron bombardment induced conductivity, means for applying a potential thereacross, photoelectronic means for generating photoelectrons, said photoelectronic means being aligned with said member so that said photoelectrons strike it, thereby rendering it conducting, and produce a charge on the surface thereof remote from said photoelectronic means, and electron beam means aligned with said member so that the beam strikes the latter

thereby removing said charge, said insulating member having a conducting layer on the side thereof near the photoelectronic means and also a conducting layer on the side thereof adjacent said electron beam producing means.

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REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
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2,256,462	Iams	Sept. 16, 1941
2,401,786	Law	June 11, 1946