

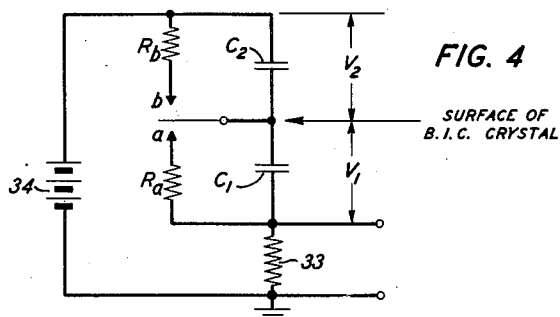
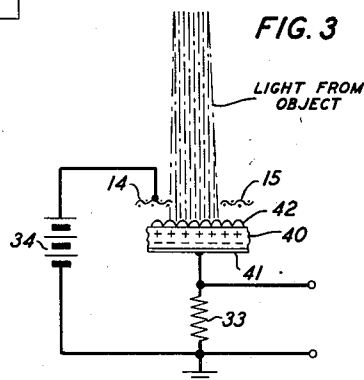
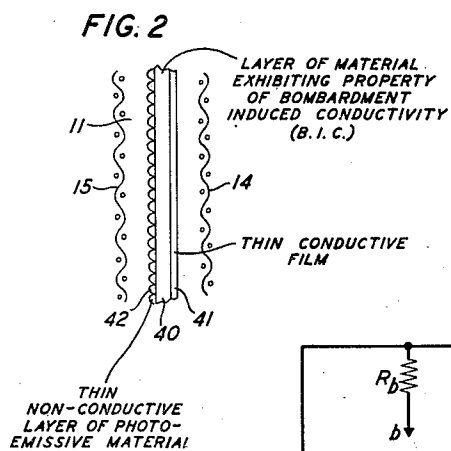
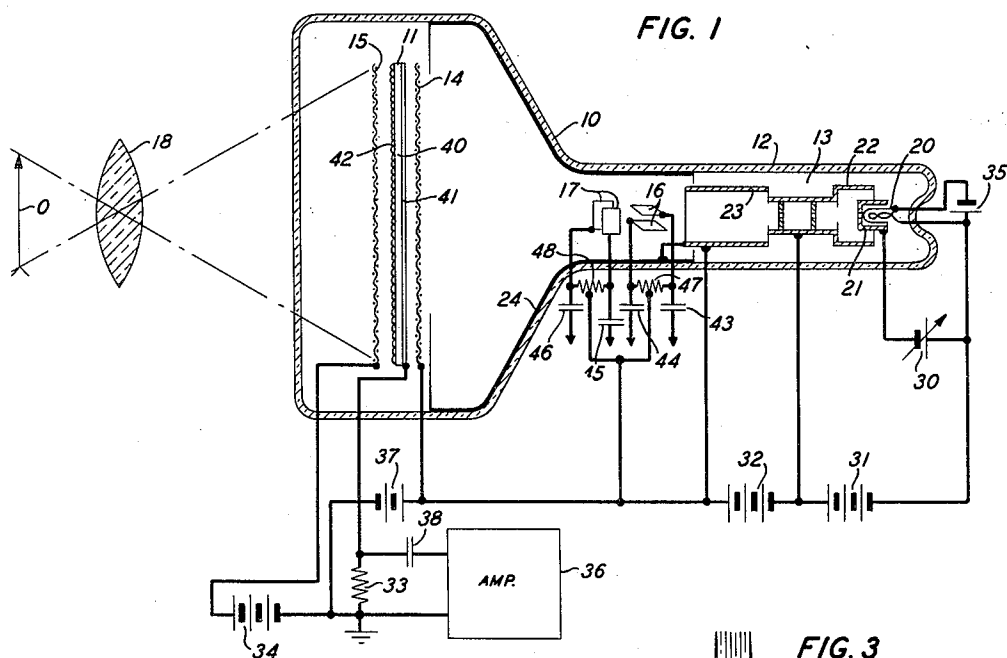
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2,544,755

ELECTRON CAMERA TUBE

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ELECTRON CAMERA TUBE

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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.

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

When electron bombardment removes a valence

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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 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. More specifically, 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 the other side is covered with a very thin layer of a non-conducting material which is photoemissive. An image of an object or field of view is applied to the photoemissive side of the target while the other side is scanned by a beam of electrons generated in the camera tube. Mesh grid members are mounted on opposite sides of the target and are spaced a short distance therefrom. Externally produced secondary electrons are collected

on the grid nearer the conducting layer side of the target while photoelectrons are collected by the other grid member.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings 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 electron collecting electrodes in the tube shown in Fig. 1; and

Figs. 3 and 4 are diagrammatic representations to aid in understanding 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 crystals 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; electron collecting electrode 14 on the side of the target 11 near the gun 13, a photoelectron collecting electrode 15 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 side of the mosaic target 11 remote from the electron gun 13 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 and a coating 24 of conducting material on the inside walls of the envelope 12 extending from the region of the cylinder 23 to the region of the mosaic target 11. The collecting electrode 14 for the secondary electrons emitted from the target 11 when it is struck by the beam of high velocity electrons preferably consists of mesh material. The photoelectron collecting electrode 15 on the other side of the target 11 is also preferably of mesh material.

The control electrode 21 is placed at any suitable negative potential with respect to the potential of the cathode 20 by means of an adjustable source 30; and the first anode 22 and the final anode 23, 24 are placed at appropriate positive potentials with respect to the cathode 20 by means of the source 31 and the source 32. As an example, the final anode 23, 24 can be in the range from 1,000 to 10,000 volts or more positive with respect to the cathode and the first anode 22 can be, for example, 300 volts positive with respect to the cathode. 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, while the negative terminal of the source 22 is connected to the positive terminal of the source 31 and the positive terminal of source 32 is connected to the second anode 23, 24. Preferably the positive terminal of the source 32 is connected to ground through a source 37 which is used to make the electrode member 14 positive with respect to the

target 11 for a purpose which will be pointed out hereinafter. The voltage of this source 37 can be, for example, 20 to 50 volts. Batteries have been shown only for convenience in the drawing and it is to be understood that any other means for producing direct voltages can be used instead.

Reference will now be made to Fig. 2 which shows in enlarged scale a portion of the two-sided mosaic target 11 and its associated electrode members 14 and 15. Fig. 2 has not been drawn to scale. The target 11 comprises a thin layer 40 of insulating material which exhibits the property of electron bombardment induced conductivity. For example, the layer 40 is a very thin cut of diamond or a simulated sheet of diamond formed by a layer (preferably one particle thick) of diamond chips or diamond dust. Alternatively, any other suitable material exhibiting the property of electron bombardment induced conductivity can be used instead of diamond. The side of the layer 40 near the electron gun 13 is coated with a very thin conducting film 41 of a metal such as gold or platinum while the opposite side of the layer 40 is either left uncovered or (preferably) is covered by a very thin layer of a laterally non-conducting material which yields a larger photoresponse than diamond to light of the desired wavelength. Such a layer, for example, may be no more than a single molecule in thickness. The layer 42 may be a compound of one of the alkaline metals, such as, for example, caesium oxide, or it may be a mixture such as caesium-oxide-silver as in certain well-known commercial electron camera tubes. The layer 41 is connected through a resistor 33 to ground. The electrode 15 is connected to ground through a source 34. Any suitable amplifier 36 is connected to the signal resistor 33 through a suitable coupling condenser 38 and is in turn connected to the other elements of the television transmitter circuit which prepare the video signal for transmission to the receiving station.

The potentials applied to the various electrode members and their configurations and shapes are such that a beam of focussed high viscosity electrons strikes the target 11 and this beam is deflected over a suitable field thereon 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 circuits to the pairs of plates 16 and 17 by means of coupling condensers 43, 44, 45 and 46, respectively, of about one microfarad capacity each. Coupling resistances 47 and 48 of the order of many megohms each are respectively connected across the pairs of plates 16 and 17. The mid-points of the resistances 47 and 48 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 potential of the anode 23, 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 device shown in Fig. 1

will now be described, reference also being made to Figs. 3 and 4 which are diagrammatic representations to aid in understanding the invention. Radiations from the object or field of view O are projected upon the left-hand side of the tube 10 and strike the photoemissive layer 42 of the target 11. Photoelectrons are emitted from this surface in direct proportion to the brightnesses of the various parts of the object or field of view to be televised. These photoelectrons are attracted to the photoelectron collecting electrode 15 since this electrode is positively biased with respect to the target 11 by means of the source 34. Since the layer 42 is thin enough to be non-conductive laterally, a series of discrete charges will be built up thereon proportional in each case to the intensity of the corresponding elemental area of the object or field of view.

At the same time that a charge pattern is being formed on the left-hand side of the target 11, a beam of electrons produced by the gun 13 and deflected over a rectangular field thereof by the electrostatic deflecting fields applied between the sets of plates 16 and 17 scans the right-hand side of the target 11 through the collecting electrode 14. Any externally produced secondary electrons are collected by the collecting electrode 14 which is at a positive potential sufficient to collect all the secondaries produced. If the bombarding voltage is such as to make the target secondary emission coefficient $\delta = 1$, then no net current flows through the resistor 33. This is a desirable although not a necessary condition. As the beam traverses the diamond sheet or layer 40, it produces many electrons in the conduction band but where there is no voltage across the diamond these merely recombine with the positive holes. However, when the beam strikes a spot opposite one on the left-hand side of the target 11 from which photoelectrons have been removed and which is at a certain potential, conductivity takes place across the diamond sheet 40 and the charge produced by the removal of the photoelectrons is neutralized by electrons which flow from ground through the resistor 33 and through the diamond. Thus a pulse is produced across the resistor 33 which is applied to the amplifier 36 wherein it is amplified and then applied to other elements of the television transmitter circuit.

Reference will now be made to Fig. 3 which shows an element of the target 40 positioned near a portion of the collecting electrode 15, the collector 15 being connected to the back plate 41 of the target through source 34 and resistor 33 as in Fig. 1. Now assume that the surface 42 of plate 40 has been irradiated by light for a short time (duration of a frame). Photoelectrons have left the surface 42 for the collector 15 leaving behind a positive charge at the surface as indicated in Fig. 3 and a corresponding negative charge at the base. During this process there has been a net flow of electrons upward or a current downward in the load resistance 33. The magnitude of this current corresponds to the number of electrons leaving the whole surface of the irradiated plate 40 and is proportional to the average amount of light that falls on the plate in this interval. Since this average does not change appreciably during one frame, the current is sensibly constant and therefore carries no signal. Now a small area of the plate 40 is bombarded by primary electrons that penetrate the surface and produce

local conductivity. The charges on the opposite faces of the plate in this elemental area then become neutralized through the conducting path produced thereby. The effect of this neutralization is the same as that of positive charge flowing downward through the plate 40 and through the resistor 33, the current being proportional to the charge built up in this area since the last scan, which in turn is proportional to the illumination of this area during time between scans. As the scanning beam moves over the surface the current in the resistance 33 due to the neutralized charge varies with the illumination from point to point on the surface constitutes a signal current.

There is still another way of looking at the operation of the arrangement of Fig. 1. In Fig. 4, the plate 40 is represented by the condenser C₁ with the base and top surface as electrodes, and the condenser C₂ is formed by the surface and the collector electrode 14. A switch with contacts a and b connects either the resistance R_a across C₁ or R_b across C₂. The current through R_b represents photoelectrons charging the condenser C₂ and that through R_a current flowing through the plate 40 by virtue of the induced conductivity which tends to discharge C₂, the potential on C₁ varying in very nearly the opposite sense. A mathematical analysis of this circuit yields an answer in very complicated terms but qualitatively the answer is that on closing the switch a transient signal current flows through the load resistance 33 as expected, depending in magnitude on the resistance R_b.

The arrangement shown in Fig. 1 is capable of very large output current due to the electron bombardment induced conductivity as much larger output current can be produced than the photoelectrons producing the individual charges. Moreover, due to the fact that the target is of the two-sided type, the photoelectrons and the beam are separated with consequent advantages in tubes of this type.

Various modifications can be made in the embodiment described above without departing from the spirit of the invention, the scope of which is indicated in the claims.

What is claimed is:

1. An electron camera tube comprising a target for electrons including an array of particles of an electrical insulating material which has the property of becoming conducting when bombarded with electrons.

2. An electron camera tube comprising a target for electrons including material which is normally insulating but which has the property of becoming conducting when bombarded with electrons.

3. An electron camera tube comprising a target for electrons including an array of crystals of an electrical insulating material which has the property of becoming conducting when bombarded with electrons.

4. An electron camera tube comprising a target for electrons including a layer of electrical insulating material which has the property of becoming conducting when bombarded with electrons.

5. An electron camera tube comprising a target for electrons including a thin, continuous crystalline layer of an electrical insulating material which has the property of becoming conducting when bombarded with electrons.

6. An electron camera tube comprising a target for electrons including a thin, substantially continuous layer of crystals of an electrical insulator

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which has the property of becoming a conductor when bombarded with electrons.

7. An electron camera tube comprising a target for electrons including a thin layer of an electrical insulator which has the property of becoming a conductor when bombarded with electrons, a continuous metallic coating on one side of said crystalline layer and a thin coating of photoemissive material on the other side thereof.

8. An electron camera tube comprising means for generating a beam of electrons and a target positioned to have one side thereof impinged by said beam, said target comprising a thin layer of an electrical insulating material which has the property of becoming conducting when bombarded by electrons, and a continuous metallic coating on said layer on the side thereof toward said beam generating means.

9. An electron camera tube comprising means for generating a beam of electrons and a target positioned to have one side thereof impinged by said beam, said target comprising a thin layer of an electrical insulating material which has the property of becoming conducting when bombarded by electrons, a continuous metallic coating on said layer on the side thereof toward said beam generating means, and a photoemissive layer on

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said insulating material on the side thereof remote from said metallic coating.

10. An electron camera tube comprising means for generating a beam of electrons, a target positioned to have one side thereof impinged by said beam, said target comprising a thin layer of an electrical insulating material which has the property of becoming conducting when bombarded by electrons, a continuous metallic coating on said layer on the side thereof toward said beam generating means, and a photoemissive layer on said insulating material on the side thereof remote from said metallic coating, and mesh collecting electrodes on respectively opposite sides of said target.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,251,992	Flory et al.	Aug. 12, 1941
2,256,462	Iams	Sept. 16, 1941