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ELECTRON CAMERA TUBE
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FIG. 1

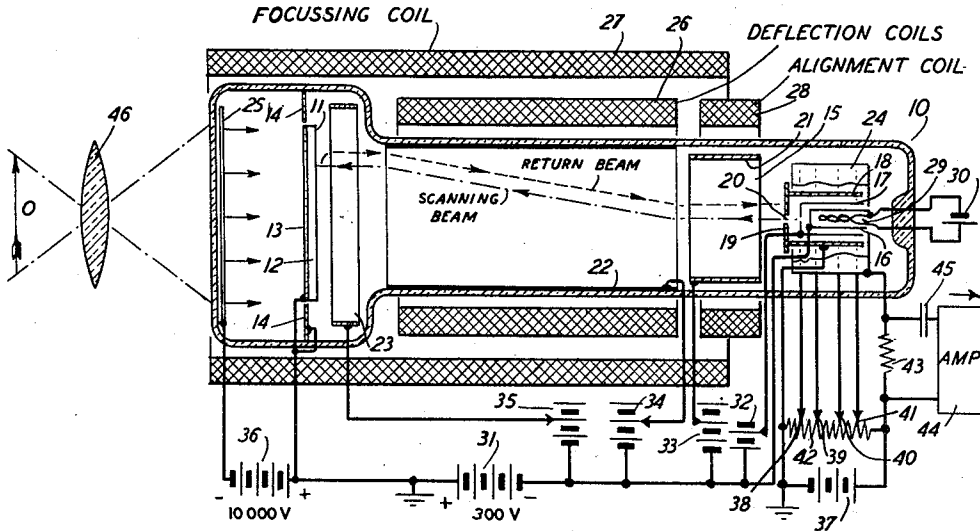
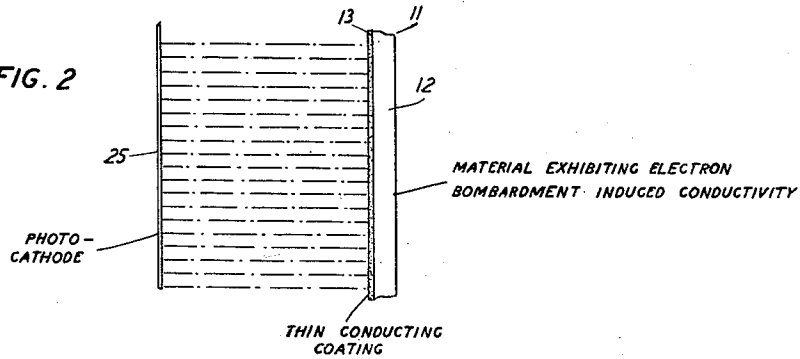


FIG. 2



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ELECTRON CAMERA TUBE

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8 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 electron camera tubes of the image orthicon type.

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 charge rate represented by 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 inhibiting 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. A single bombarding electron may free a large number of electrons and positive holes, depending upon its impact energy. This large number of charged particles is then available for conduction current, so that considerable charge multiplication can be obtained. 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 a preferred material for reasons given above. More specifically, the camera tube is generally similar to that type of commercial tube known as the image orthicon and which is described in detail in an article by Messrs. Rose, Weimer and Law on page 424 of the Journal of the Institute of Radio

Engineers for July 1946. The camera tube of the present invention includes, however, a two-sided mosaic comprising a mosaic layer of diamond or other crystals exhibiting the property of electron bombardment induced conductivity, the diamond layer being coated on one side with a thin conducting layer while the other side is left uncoated. The coated side is struck by image-modulated high velocity photoelectrons while the other side is scanned by an electron beam which has practically zero velocity at the target in the absence of charges produced thereon by the signal-modulated photoelectrons but which has a positive velocity dependent on the degree of charge at those elemental areas of the target which are affected by the photoelectrons. An electron multiplier receives and multiplies the electrons given off by the target during the scanning to produce the output signal. An advantage of the tube of the present invention is that it is comparatively free from stray secondary emission trouble. Another important advantage is the very considerable internal charge multiplication in the crystal. Other advantages and features will be apparent as the description proceeds.

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 apparatus; and

Fig. 2 is a schematic view showing, in greatly enlarged form, a portion of the target and of the photoelectric cathode associated therewith.

Referring more particularly to the drawing, Fig. 1 shows, by way of example to illustrate the invention, a cathode ray television transmitter tube 10 generally of the image orthicon type described in the Rose, Weimer and Law article mentioned above but employing, instead of the thin glass target and its accompanying fine mesh screen, a two-sided mosaic target 11 containing material exhibiting the property of electron bombardment induced conductivity. The target 11 comprises a layer or sheet 12 of material exhibiting the property of electron bombardment induced conductivity coated on one side with a very thin conducting coating 13 of, for example, gold or platinum. For example, the layer 12 is a very thin cut of diamond or a simulated sheet of diamond formed by a crystalline layer (preferably one particle thick) of diamond chips or diamond dust. Alternatively, any other suitable material exhibiting the property of bombardment induced conductivity can be used instead of diamond. The layer 12 can be of the order of a millimeter thick, for example. Surrounding the target is a metallic barrier 14 which prevents photoelectrons from passing around the target into the space at the right of the target in Fig. 1. The elements 13 and 14 can be placed at the same potential, if desired. The tube 10 comprises an evacuated container enclosing the mosaic target 11, an electron-optical system 15 for producing an electron beam and including a cathode 16, a control electrode 17, an accelerating electrode 18 having a relatively large aligning disc 19 with an aperture 20 therein, a cylinder 21, a metallic anode member 22 which is preferably a coating on the inside walls of the tube, and a metallic alignment ring 23. The tube 10 is also provided with an electron multiplier 24 of any suitable type but which is preferably of the "pin-wheel" type used

in the commercial image orthicon. A photosensitive surface 25, preferably on the inside wall at the end of the tube 10, serves as a photocathode. External to the tube 10 are a deflection yoke or coils 26, a focussing coil 27 and an alignment coil 28 similar to corresponding members in the image orthicon and the purpose of which will be described more fully below.

The cathode 16 is heated by any suitable heater 29 receiving current from a source 30. The cathode 16 is placed at a potential of, for example, -300 volts (but which may, for example, be appreciably higher) with respect to ground by means of a source 31 whose positive terminal is grounded and whose negative terminal is connected to member 16. The adjustable source 32 holds the control electrode 17 at a suitable negative potential with respect to the cathode 16. Electrode 18, with its apertured disc 19, is connected to ground. Electrode 21 is held at roughly 200 volts positive with respect to the cathode by means of adjustable source 33, whose negative terminal is connected to the negative terminal of source 31. The coating 22 is connected to the cathode through an adjustable source 34 of such value that it is roughly 250 volts positive with respect to the cathode. The metal ring 23 is placed at a suitable positive potential with respect to the cathode by means of an adjustable source 35. The metal coating 13 on the target 11 is placed at the potential of ground while the photoelectric cathode 25 is placed at a potential of about 10,000 volts below ground by means of a suitable source 36. The highest potential of the electron multiplier 24 is about 1500 volts positive with respect to ground and this potential is applied by means of source 37, the negative terminal of which is connected to ground and to the alignment disc 19 which actually is the first electrode of the multiplier. Various intermediate potentials for the intermediate electrodes of the electron multiplier 24 are provided by means of taps 38, 39, 40 and 41, respectively, of a potentiometer resistor 42 connected across the source 37. The positive terminal of the source 37 is connected to the final anode or collector of the multiplier 24 through an output resistor 43. Connected across the resistor 43 is an output amplifier 44, the coupling circuit of which includes a coupling condenser 45. The amplifier 44 is in turn connected to the other elements of the television transmitter circuit which prepare a video current for transmission to the receiving station.

The operation of the arrangement shown in Fig. 1 will now be described, reference also being made to Fig. 2 which is an enlarged view of a portion of the mosaic target 11 and the photocathode 25. Certain dimensions in Fig. 2 have been exaggerated at the expense of others in order to more clearly show the screen structure. It is to be understood that relative dimensions shown in Fig. 2 are not necessarily those which exist in a tube constructed in accordance with the invention. Radiations from an object or field of view O are projected upon the left-hand side of the tube 10 and strike photocathode 25, these radiations being focussed by any suitable lens system represented schematically by the single lens 46. Photoelectrons are emitted from the photocathode 25 in direct proportion to the brightnesses of the various parts of the object or field of view to be televised. The photoelectrons released from the member 25 are accelerated from this member towards the mosaic target 11 by a uniform electric field produced by the source

36 connected between the member 25 and the conducting coating 13 of the target 11. The field strength between the cathode 25 and the coating 13 is made very high, so that the effect of emission velocities is small. Thus the charge array leaving the photocathode 25 is substantially imaged on the coating 13. The magnetic field parallel to the axis of the tube, produced by focussing coil 27, also exerts some focussing action. As indicated in Fig. 2, the paths of the photoelectrons between the members 25 and 13 are substantially straight lines parallel to the axis so that the electron image has unity magnification. These photoelectrons strike the target 11 at about 10,000 volts velocity. This potential is not in any way critical but it should be relatively high. These photoelectrons shoot through the metal coating 13 and bombard the layer or particle array 12, freeing electrons and "positive charges" or "holes." The uncoated face of the layer 12 is kept at the potential of the thermionic cathode 16, that is, about 300 volts negative with respect to the metal coating 13 (which is grounded) by the very low velocity scanning beam generated by the electron gun. This difference in potential between the two sides of the layer 12 sets up a polarizing field which effectively moves the freed positive holes through the layer 12 of crystal (or crystal particles) across to the uncoated side, reducing its negative charge. The magnitude of this positive charge current reaching any given elementary region of the uncoated face of the layer 12 will be proportional to the photoelectron current bombarding the corresponding region of the metal coating 13. Due to the phenomenon of internal charge multiplication in the crystal, the positive charge current can be many times the photoelectric current from the member 25. The positive charge increment on a given elementary region of the uncoated face of the layer 12 accumulates for a frame time under the influence of the radiations from the object O.

At the same time that a charge pattern is being accumulated on the layer 12, a beam of electrons scans the uncoated side of this layer. The scanning beam is of the low velocity type used in the commercial image orthicon tube. The beam starts at the thermionic cathode 16 at a potential of about -300 volts (with respect to ground) and is accelerated by the electron-optical system 15 to approximately zero volts (actually 300 volts positive with respect to the cathode). From the cathode 16 to the target 11 the beam is acted upon by the approximately uniform magnetic focussing field produced by the coil structure 27 and the transverse magnetic field produced by the deflection coils 26. The beam leaves the aperture 20 parallel to the axis, is deflected by the transverse magnetic field during the middle part of its trajectory, and finally approaches the layer 12 substantially at normal incidence; that is, parallel to the axis again. As the beam electrons approach the target they are decelerated again to approximately cathode potential, that is -300 volts. If there is no positive charge increment on the layer 12, all the electrons are reflected and return toward the cathode 16 along their initial paths as indicated in Fig. 1. If there is a positive charge pattern on the layer 12, the electrons from the beam are deposited in sufficient numbers to neutralize the positive charge increment thereon and restore the potential of the region to that of the cathode, that is, about -300 volts. The remaining electrons are re-

flected back toward the cathode as indicated in the drawing. Under equilibrium conditions, all the beam current is returned to the electron multiplier 24 concentric with the cathode 16. Before equilibrium is reached, the number of electrons in the return beam is reduced by the amount required to neutralize the positive charge increments on the layer 12. This reduction in intensity of the return beam to the electron multiplier 24 constitutes the video signal information.

The return beam arrives in the region of the cathode 16 very near the defining aperture 20 through which it emerged but considerably enlarged in cross-section. This return beam strikes the disc 19 at a sufficient velocity to generate a larger number of secondary electrons than there are primary electrons in the returning beam. This disc 19 (as pointed out above) serves as the first stage of the electron multiplier 24, the secondary electrons from it being focussed into the succeeding stages of the multiplier 24 which are arranged concentric with and behind this first stage, the whole multiplier being represented in the drawing by the structure 24. The number of stages of the electron multiplier need not be large; for example, five stages (or less) of electron multiplication is sufficient. The type of multiplier used in the image orthicon tube is satisfactory for this purpose.

The output current from the final stage of the multiplier 24 is taken from the resistor 43 and applied through the coupling condenser 45 to the wide band television amplifier 44 where it is amplified and applied, as above described, to other elements of the television transmitter circuit.

The alignment coil 28 is used, as in the image orthicon, to correct for helical motion resulting from misalignment of the electron gun and the magnetic field produced by the focussing coil 27. The position of the ring 23 and the potential thereof are chosen to correct for helical motion resulting from the deflection fields produced by the yoke 26, also as in the well-known image orthicon type of tube.

One advantage of the tube of this invention is its freedom from stray secondary electron emission trouble. Another important advantage is the very considerable internal charge multiplication in the crystal. Also it is possible to build up a potential variation over the crystal face of many volts as compared with the approximately one-volt limitation of the commercial model of the image orthicon tube. This makes it possible to obtain much higher signal-to-noise ratios, and eases the requirement of making the approach energy of the beam constant over the target area.

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 appended claims. The specific potentials applied to the various elements are herein given merely by way of example and it is to be understood that their values may be made materially different without changing the general method of operation of the device described herein. For example, the type of crystal material used and its thickness materially affect the operating potentials required.

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 an electronic conductor when bombarded with a beam of low velocity 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 said beam of electrons.

2. An electron camera tube comprising a target for electrons including a layer of an electrical insulating material which has the property of becoming an electronic conductor when bombarded with electrons, and means for scanning said target with a beam of low velocity electrons.

3. An electron camera tube comprising a target for electrons including a layer of an electrical insulating material which has the property of becoming electron-conducting when bombarded with electrons, and means for bombarding one surface of said target with photoelectrons.

4. An electron camera tube comprising a target for electrons including a layer of an electrical insulating material which has the property of becoming electron-conducting when bombarded with electrons, means for bombarding one surface of said target with photoelectrons, and means for scanning the opposite surface of said target with a beam of electrons.

5. An electron camera tube comprising a target for electrons including a layer of an electrical insulating material which has the property of becoming electron-conducting when bombarded with electrons, means for bombarding one surface of said target with photoelectrons, and means for scanning the opposite surface of said target with a beam of low velocity electrons.

6. An electron camera tube comprising a target for electrons including a thin layer of electrical insulating material which has the property

of becoming electron-conducting 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 electrons.

7. An electron camera tube comprising a target for electrons including a thin layer of electrical insulating material which has the property of becoming electron-conducting 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 low velocity electrons.

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

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REFERENCES CITED

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

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