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Forgue

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[54] **TARGETS FOR TELEVISION PICKUP TUBES**

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[52] **U.S. Cl.** ..... **315/11,** 313/65 T

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search** ..... 313/65, 67, 68, 65.1, 66, 313/89, 65 T, 65 AB; 317/235 A, 235; 315/10, 11, 12

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[57] **ABSTRACT**

An improved target for a television camera tube comprises a single layer of material with portions of the material treated to form a P-type region, while other portions may be treated to form a N-type region. Between these regions is an intrinsic region including a rectifitying junction. Either the P-type region or the N-type region may be seanned by an electron beam, depending upon the type of operation, from a conventional electron gun.

10 Claims, 4 Drawing Figures

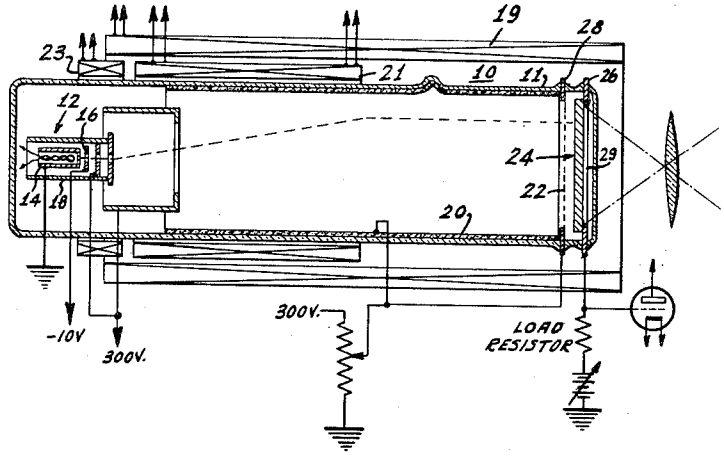


Fig. 1.

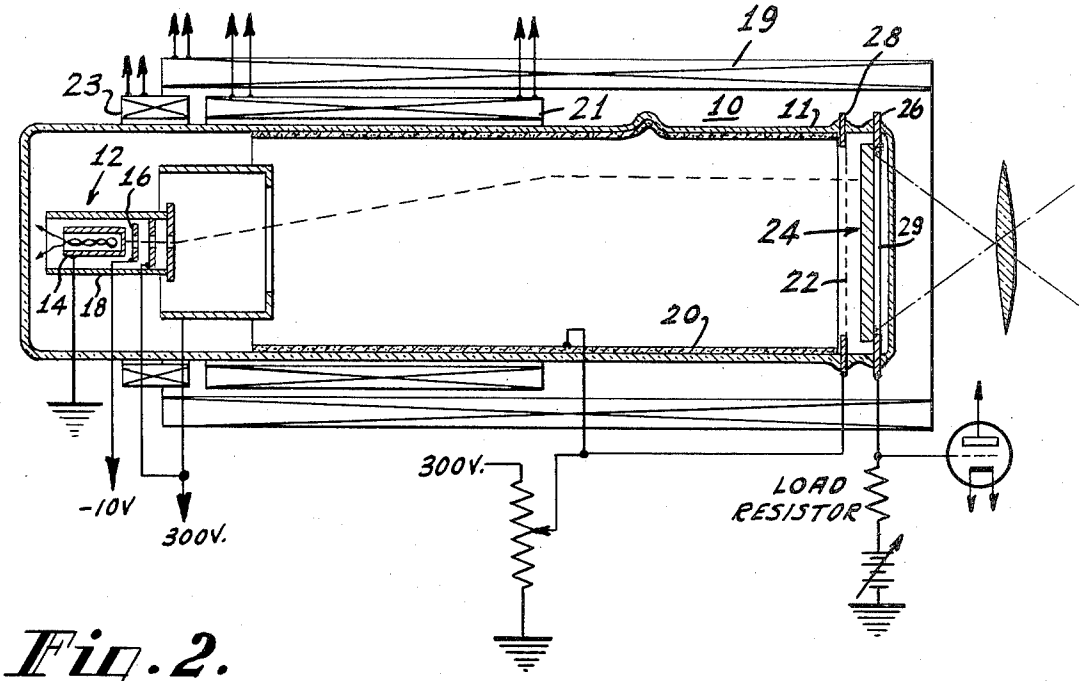
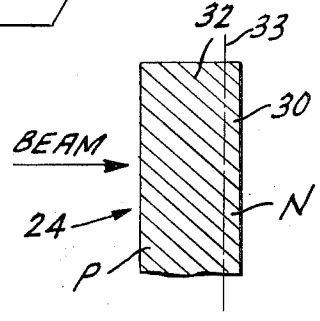


Fig. 2.



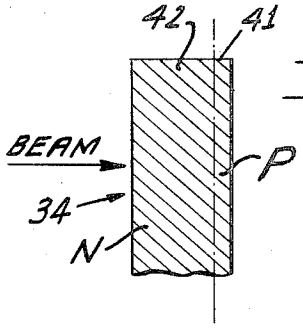
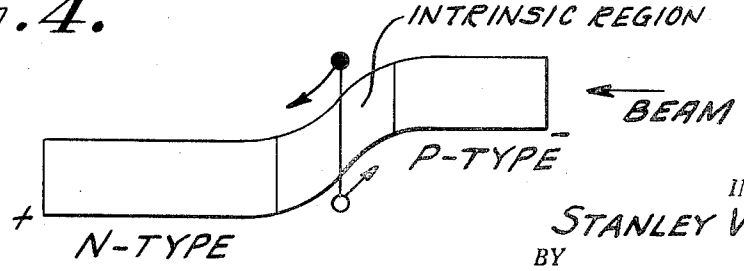


Fig. 3.

Fig. 4.



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TARGETS FOR TELEVISION PICKUP TUBES

This invention relates to television pickup, or camera, tubes. In particular this invention relates to improved target structures for television pickup tubes.

In the past there have been various structures for television pickup tubes and for targets therein. Normally the targets have fallen within the two broad classes of photoemitting surfaces and photoconducting surfaces. Targets including photoconductive surfaces require photoconductive materials having a resistivity in the dark of at least 10^{11} ohm centimeters in order to retain stored information for the one-thirtieth of a second frame time of the standard television scanning rate. Targets having photoconductive materials of low resistivity in the dark become charged in the dark areas as well as those areas where conduction is produced by photo-action. Thus, the discharging effect of the electron beam is undistinguishable in both the light and dark areas of the target, and the output or video signal of the tube has no distinguishable modulation. Because of this resistivity limitation, certain photoconductive materials, which are otherwise desirable, are eliminated from use in pickup tubes.

Photoconductive materials are normally quasi-insulators in the dark. In photoconductive materials, when an electron is removed from its bond in its atomic structure, there is established in the material a localized positive, electron deficiency region called a hole. In some materials the hole has a freedom of motion while the electron is quickly trapped and prevented from passing through the material with the same facility as the hole. In these materials the hole may move through the material haphazardly because of thermal agitation, and also in a given direction when an electrostatic field is impressed across the material. The hole being positive can be considered as a positive charge carrier and moves from plus to minus under the urging of the impressed electrostatic field. Materials in which the holes have a greater mobility, or in which there is an excess of holes produced, may be referred to as P-type materials; that is, in P-type materials the majority of the charge carriers are holes. In other materials known as N-type materials, an electron removed from its atom has a greater freedom of motion through the material than the hole formed by its removal, or a greater number of electrons are present than holes. In N-type materials, therefore, the majority of charge carriers are electrons.

A third type of material is an intrinsic material which is one in which the holes and electrons formed in the material are present in equal numbers. Both carriers may contribute significantly to electrical conduction through the material under the urging of an applied electric field. Materials of all three types are known, that exhibit photoconductive properties, but which have resistivities that are too low for storage tube operation.

As described, when there is no electric field applied to the photoconductor the free electrons, or free holes, move in accordance with thermal agitation and in a completely random motion. An electric field applied across the photoconductor, which is the case during a pickup tube operation even in the dark, provides a directional motion superimposed on the random motion. When the resistivity of the photoconductor is too low, the conductivity by free electrons, and/or free holes, is high and these free electrons, or free holes, produce a current through the material in the dark that cannot be distinguished from a current produced by light falling on the material. Also, when the random motion of free holes or electrons is too large, a charge established by light is diffused by this random motion and is therefore not stored until the electron beam re-scans the "charged" area.

Photoconductive targets for pickup tubes have been made prior to this invention that have included P–N junctions with all of their appended benefits. However, these targets have been difficult to manufacture in that they have utilized separate layers of materials for the P-type layer and for the N-type layer, with a certain amount of interdiffusion between the layers to form the intrinsic region. When using the separate layers certain problems have been encountered in manufacturing these targets such as obtaining the proper amount of interdiffusion of the layers to provide the desired inherent barrier height at the junction.

It is therefore an object of this invention to provide a new and novel pickup tube.

It is another object of this invention to provide a new and improved target structure for use in a pickup, or camera, tube.

It is a further object of this invention to provide an improved pickup tube target which permits the use of materials having resistivities, in the dark, that are less than 10^{11} ohm centimeters.

It is still a further object of this invention to provide an improved pickup tube having a target of a single layer of material and one wherein the target includes a P–N junction.

These and other objects are accomplished in accordance with this invention by providing an improved target for a television pickup or camera tube. The target comprises a single layer of material with portions of the material treated to form a P-type region, while other portions may be treated to form a N-type region. Between these regions is an intrinsic region including a rectifying junction. Either the P-type region or the N-type region may be scanned by an electron beam, depending upon the type of operation, from a conventional electron gun.

The invention will better be understood by reference to the following specification when read in conjunction with the accompanying single sheet of drawings wherein:

FIG. **1** is a sectional view of a pickup tube in accordance with this invention;

FIG. **2** is an enlarged fragmentary sectional view of the target shown in FIG. **1**;

FIG. **3** is an enlarged fragmentary sectional view of an embodiment of a target structure in accordance with this invention; and,

FIG. **4** is a schematic representation of the energy states within the targets in accordance with this invention.

Referring now in detail to FIGS. **1** and **2** there is shown a pickup tube **10** comprising an evacuated envelope **11** having an electron gun **12** in one end thereof. The electron gun **12** comprises a conventional cathode **14,** control electrode **16,** and one or more accelerating electrodes **18.** A final accelerating electrode **20,** which is in the form of a conductive coating on the inside of envelope **11,** extends from the gun **12** to the other end of elongated envelope **11.** Extending across the other

end of the accelerating electrode **20** is an apertured screen **22,** which is electrically connected by means of a ring **28** sealed thereto, and which is permeable to the electron beam from gun **12.** The screen **22** acts as an electron collector electrode during certain types of tube operation, and provides a uniform decelerating field in other types of operation. Adjacent to the screen **22** is a target electrode **24,** a sectional portion of which is shown more clearly in FIG. **2.**

Surrounding the envelope **11** is a conventional focusing and deflection system that may include a focus coil **19,** a deflection yoke **21** and an alignment coil **23.** The focusing coil **19** focuses the electron beam onto the target **24.** The deflection yoke **21** deflects the focused beam over the surface of target **24** in a conventional raster pattern.

The target electrode **24** is arranged normal to the axis of the electron gun **12.** The target **24** may be self supporting, or may be mounted on a transparent plate (not shown) when a very thin target is desired. The target **24** is positioned in the envelope **11** by being bonded to a ring **26.** The ring **26** extends through the walls of envelope **11** so that electrical contact may be made to the target **24.** The ring **26** may be bonded to the target **24** by means of suitable paste such as silver paste or sauereisen cement.

It has been found that when a P-type region and an N-type region are in contact, a rectifying effect is produced when a voltage is impressed across the target through their regions of contact. Greater resistance to current flow through the two regions occurs when the voltage is impressed across the regions by applying a more negative potential to the exposed surface of the P-type region than that applied to the exposed surface of the N-type region. This application of potential is hereinafter referred to as a reverse bias since it increases the resistance to current flow. It is believed that the P-type region and the N-type region are interdiffused at their interface so as to form an intrinsic region which is a rectifying junction. This rectifying junction conducts both electrons and holes, but the electrons are conducted in substantially one direction only, while the holes are conducted in substantially only the opposite direction.

During operation, potentials are applied to the tube **10** such as those shown in FIG. **1.** The target **24** may comprise a single material in which the target surface facing the electron beam is P-type region, and the surface electrically connected to support ring **26** is N-type region with an intrinsic region between the target surfaces. FIG. **2** shows a typical target in which the intrinsic region is represented by dotted line **33.**

As can be seen from the drawing, the target **24** is electrically energized by having a potential applied to the N-type region **30.** In accordance with an embodiment of this invention the N-type region **30** is sufficiently conductive for this application of potential. In other words the N-type region **30** acts as the signal plate for the target **24.** It should be understood that a separate signal plate may be utilized with the target **24** but, as will be explained hereinafter, a separate signal plate is not normally necessary. The potentials shown in FIG. **1** are for a type of operation known as low velocity electron beam scanning. In this type of operation the N-type region, or signal plate, **30** (FIG. **2**) is maintained at a potential that is slightly positive with respect to the cathode **14.** Electrons from cathode **14** are formed into an electron beam by electrodes **16** and **18** and are accelerated down the tube toward target **24** by the accelerating field of electrode **20.** The beam is focused to a small spot on the surface of target **24** and is scanned over the target surface in a substantial rectangular raster by the field of deflection yoke **21.** The beam is slowed down as it approaches the surface of region **32** by the decelerating fields established between mesh **22** and target **24.** Thus, at first, the electrons of the beam land on the exposed surface of photoconductive region **32** at energies less than enough to provide a secondary electron emission from the surface of region **32** greater than the current of the beam striking the target. This results in the scanned target surface being driven in a negative direction to establish a reference potential, in the dark, that is substantially equal to the potential of cathode **14.** The electrons of the beam are then reflected from areas of the target surface of region **32** which are at reference potential. Reflected electrons from the target return down the tube toward gun **12** where they are collected by more positive electrodes in the tube.

The target shown in FIGS. **1** and **2** may also be operated with a type of operation that is known as high velocity positive type of operation. In this type of operation the screen **22,** which functions as a collector of secondary electrons, is operated at a potential that is slightly negative with respect to the signal plate **30,** which in turn is made highly positive, e. g., several hundred volts, with respect to the cathode **14.** When using high velocity positive operation, the electron beam strikes region **32** with energies of several hundred volts and releases more secondary electrons from the target than primary beam electrons landing on the target. The secondary electrons are redistributed, or driven back, onto the target due to the negative, or repelling, potential on the collector screen **22.** As a result, the secondary electrons are redistributed on the target until the scanned surface of the target is driven, in a negative direction, to establish a reference potential substantially equal to that of the collector electrode **22** and negative to the potential of signal plate **30.**

It should be noted that when the target shown in FIGS. **1** and **2** is operated in either the low velocity method, or the high velocity positive method, the P–N junction is operating under reverse bias conditions. In other words, for these methods of operation, the P-type region **32** is biased negatively by the beam and the N-type region **30** is biased positive by the potential supplied thereto. This biasing is the reverse direction across the rectifying junction, since the P-type region **30** normally conducts holes, i. e. the absence of electrons, while the N-type region **32** conducts electrons. This direction of bias brings about a minimum leakage or dark current through the carrier region between the P- and N-type surfaces.

Referring now to FIG. **4** there is shown a schematic representation of the energy levels of a target of the type shown in FIGS. **1** and **2.** From this representation it is seen that the intrinsic region between the P and N regions includes a wide rectifying barrier or junction in the potential distribution. This intrinsic region, as was described above, is a region where both electrons and holes are conducted in substantially the same amounts. The barrier in the potential distribution is rather sharp due to the reverse bias that is placed across the P-N junction. Without this reverse bias there is a potential

barrier between the P and N regions, due to the nature of the materials. However, with the reverse bias the potential barrier is magnified so that the electrons are pulled more strongly toward the signal plate **30** while holes are pulled more strongly towards the scanned surface of the P-type region **32.**

The reverse bias operation of the target **24,** because of the rectifying junction, provides a sufficient dark resistivity, in the order of 10^{11} ohm cm. across the target **24,** so that the target **24** is usable for pickup tube operation even though the material used to form the target may be of lower usable resistivity.

Targets of the type shown in FIG. **2,** may be manufactured as follows:

A P-type material may be formed by "doping" or introducing impurities of gold and boron, or indium, for example into a crystal of silicon which results in a very high resistivity through the material. Then the P-type base layer of gold-boron, or gold-indium, doped silicon, has formed at one surface thereof an excessively gold doped N-type region. As an example; to 100 grams of silicon that has been doped with 1 micro gram of boron, i. e., the P-type base, 2.5 grams of ultra pure gold is added to form the N-type region. Another example of this type of target is a crystal made of 100 grams of high purity germanium which is made P-type by doping with 500 milligrams of germanium which has previously been doped with about 15 micrograms of arsenic per cubic centimeter of germanium, and the N-type region is formed by adding 450 milligrams of high purity gold to the mixture.

The type of target described above and shown in FIG. **2** appears to be especially promising for low velocity beam pickup tube applications, since the N-type region is biased positively and faces the impinging light.

This arrangement places the intrinsic region on the light impinging side so that there is no excessive absorption of the light before it reaches the intrinsic region. Doubly impurity doped silicon and germanium have both exhibited high dark resistivity above 10^{11} ohm cm. by the balancing of impurities which makes them particularly valuable for pickup tube work.

Referring now to FIG. **3** there is shown an embodiment of this invention comprising a target **34.** Target **34** comprises a P-type region **41** formed in a N-type base material **42.** In this embodiment the N-type base material **42** may be scanned by the beam and the P-type region **41** may act as the signal plate as described above.

Targets of the type shown in FIG. **3** may also be made is several ways, for example this type of target, i. e., one including an N-type base region, and a formed P-type region may be made of crystals such as germanium or silicon doped with arsenic, which are treated with an etch on one surface to form the P-type region. An etch for this purpose may be formed as follows: 25cc of nitric acid; 15 cc of hydrofluoric acid; 15cc of glacial acetic acid; and 0.3cc of bromine. When this type of target is used a N-type crystal of either germanium or silicon, that is approximately 3 to 5 mils thick, may be etched a few tenths of a mil, e. g., approximately 0.2 of a mil to form the P-type region.

Thus, a N-type germanium crystal etched as described above is mounted within the tube with the thin P-type etched region facing the beam. The N-P junction area thus formed is very sensitive to radiation of wavelengths shorter than 1.8 microns. Here, the N-type base material is much too low in resistivity for frame storage operation. In fact the resistivity is so low that the N-type region acts as its own signal plate. However, the action of the reverse biased P-N junction between the P and N regions produces a low dark current consistent with frame storage resistivity. Very high visible and infrared sensitivity have been observed with no lag. When the target is used in low velocity beam operation, described above, the visible light should impinge from the scanned side of the target for the base material absorbs highly. However, for infrared pickup tube operation the radiations may impinge on either side since the N-type germanium material does not absorb the infrared radiations to any great extent. The described arrangement of an N-type base of silicon having a P-type region formed by etching, has operated with frame storage resistivity and infrared light sensitivity in the hundreds of microamperes per lumen range when the target **34** is operated at dry ice temperatures. Another example of a method of manufacturing a target of the type shown in FIG. **3** is to etch a crystal of P-type germanium with an etch of hydrogen peroxide to form the N-type layer.

Targets of the N-type germanium with evaporated gold dots on one surface to form the P-type region have also been made and tested. These targets are then heated to a temperature above the eutectic point to interdiffuse the gold with the germanium and form the P-type region. This type of a target has exhibited good light sensitivity.

When the beam and light strike opposite sides of the target to establish reverse bias conditions across the target shown in FIG. **3,** a method of operation that is known as high velocity negative type of operation is used. In high velocity negative operation collector electrode **22** is operated at a potential that is slightly positive, of the order of 10 volts, with respect to the signal plate, or P-type region **41** which in turn is highly positive, of the order of 300 to 400 volts, with respect to the gun cathode **14.** When using this type of operation the electron beam releases more secondary electrons from the N-type region **42** than primary electrons land on this layer. Due to the potentials applied, the secondary electrons are collected by the collector screen **22,** until the N-type region **42** is driven positively to establish a reference potential substantially equal to that of collector electrode **22.** This driving in the positive direction of the N-type region **42** establishes the reverse bias conditions that were explained above. A potential characteristic for the target **34** is substantially the same as that shown in FIG. **4** except that the characteristic is inverted and the N-type region scanned by the electron beam.

In any of the types of operation referred to above for the structures shown in FIGS. **1–3,** a reference or equilibrium potential is established on the scanned surface of the target in the dark, as described above. When light from a scene, or object, to be reproduced is directed onto the target, hole-electron pairs are set free in elemental areas of the intrinsic region of the P–N junction. Due to the potential difference across the intrinsic region these free electrons and holes are conducted in opposite directions before they can recombine with each other. Also, the barrier height is reduced in the elemental areas as the photoconductor becomes conductive under the influence of the light, so that electrons or holes that are set free by the light in

both the P-type region and the N-type region are conducted. When the holes from any portion of the target layers reach the scanned surface of the P-type region **32** they establish a charge, with respect to the reference potential, on the surface of layer **32** in the illuminated areas. When the electron beam re-scans those charged areas, it drives the areas back to reference potential and in so doing devleops output signals by the capacity coupling between the scanned surface of the P-type region **32** and the signal plate, or N-type region **30.** The signal plate **30** during operation, is connected to a load circuit in which the output signals of tube **10** are utilized.

In both of the targets shown in FIGS. **2** and **3** there is formed a series resistance to the electron beam in the dark that comprises a low resistance, a high resistance and a low resistance in that order. For example, in FIG. **2** there would be a low resistance comprising the P-type region **32,** a high resistance comprising the intrinsic region, and a low resistance formed by the N-type region **30.** These three resistances of the P–N junction targets in accordance with this invention, are believed to distinguish P–N junction targets from other targets which do not form a rectifying junction. In the targets of these prior pickup tubes it is believed that the resistive elements were limited solely to the resistance within the particular layers, and there is substantially no rectifying junction characteristics developed, since there is substantially no intrinsic region produced.

It should be understood that in either of the targets shown in FIGS. **2** and **3,** if the region which is formed in the base material does not have a low enough resistivity to act as a signal plate, then a separate signal plate, such as a thin layer of gold, may be used.

The targets described above may be treated with a non-reflecting coating on the light incident side. Such a coating may be formed of 32 grams of sodium hydroxide in 100 cubic centimeters of water. It may be utilized on the target by appling the solution on the light incident side for approximately five minutes at 75°C; then applying hydrofluoric acid for approximately five minutes at room temperature. This type of coating reduces reflections and is electrically conductive so it may be used as the signal plate.

The targets in accordance with this invention may thus be either a P-type base region having an N-type region formed on one side, or an N-type base region having a P-type region formed on one side thereof. In each of these targets there is an intrinsic region, or barrier junction, between the P-type region and the N-type region.

Thus, this invention provides improved targets for pickup tubes including a P-N junction of a single layer of material. The single layer may be either a P-type base material having an intrinsic region and a N-type region formed therein, or an N-type base material having an intrinsic region and a P-type region formed therein.

When a P-N junction is properly biased in the reverse direction as was explained above, there is only a small dark current since only a negligible number of free charges can traverse the barrier. A reservoir of holes exists in the P-type region while a reservoir of electrons exists in the N-type region. When a hole-electron pair is formed in the intrinsic region, or active junction area, due to light falling on the target from an object to be reproduced, the electron of the pair will move thorugh the junction area to the N-type region, while the hole will add a positive charge to the hole reservoir in the P-type region and upset neutrality there. Therefore, an electron can move into the circuit from the N-type region and from the beam into the P-type region, to neutralize the hole that is present in the P-type region.

When using a target in accordance with the invention the resistivity of the N or P type region facing the electron beam must be sufficient to prevent loss of the desired resolution by sideways leakage during a frame time. However, this value of resistivity can be much lower than that needed for frame storage operation of a single layer of photoconductive material used prior to this invention.

What is claimed is:

1. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target electrode comprising a single layer of photoconductive material having a dark resistivity of approximately 10^{11} ohm centimeters when biased in a reverse direction and containing a P-N junction.

2. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target electrode comprising a photoconductor containing a N-type region and a P-type region, said regions of said photoconductor being interdiffused to form a rectifying junction, and means for biasing said target in the reverse direction, one of said regions being a signal plate for said target electrode during operation of said tube.

3. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target electrode comprising a layer of silicon photoconductive material having an excess of indium comprising a P-type region, and another region of said material having an excess of gold comprising a N-type region whereby said regions comprise a P–N junction, said target having a dark resistivity of approximately 10^{11} ohm centimeters when biased in a reverse direction.

4. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target electrode comprising a layer of silicon photoconductive material comprising a P–N junction, one region of said material having an excess of boron comprising a P-type region, and another region of said material having an excess of gold comprising a N-type region, said target having a dark resistivity of approximately 10^{11} ohm centimeters when biased in a reverse direction.

5. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target electrode comprising a layer of germanium photoconductive material comprising a P–N junction, one region of said material having an excess of arsenic comprising a N-type region and another region having an excess of gold comprising a P-type region.

6. A target for a television pickup tube comprising a single layer of silicon photoconductive material comprising a P–N junction, one region of said material having an excess of boron comprising a P-type region and another region having an excess of gold comprising a N-type region, said target having a dark resistivity of approximately 10^{11} ohm centimeters when biased in a reverse direction.

7. A target for a television camera tube comprising a single layer of silicon photoconductive material comprising a P-N junction, one region of said material having an excess of indium comprising a P-type region and another region having an excess of gold, comprising a N-type region, said target having a dark resistivity of approximately 10^{11} ohm centimeters when biased in a reverse direction.

8. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target comprising a base region of N-type germanium having a P-type region etched on one side thereof, and means for producing a reverse bias across said target.

9. A television camera tube comprising an envelope, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam, said target comprising a base region of N-type silicon having a P-type region etched on one surface, and means for producing a reverse bias across said target.

10. A television camera tube comprising an envelope having a transparent section, an electron gun in said envelope for forming an electron beam along a path, a target electrode in said envelope spaced from said gun and in the path of said beam and in the path of radiant energy passing through said transparent section, said target electrode comprising a layer of silicon photoconductive material including a P–N junction, one region of said material having an excess of boron comprising a P-type region and another region having an excess of gold comprising a N-type region, and a signal plate comprising a layer of gold on one surface of said material.

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