

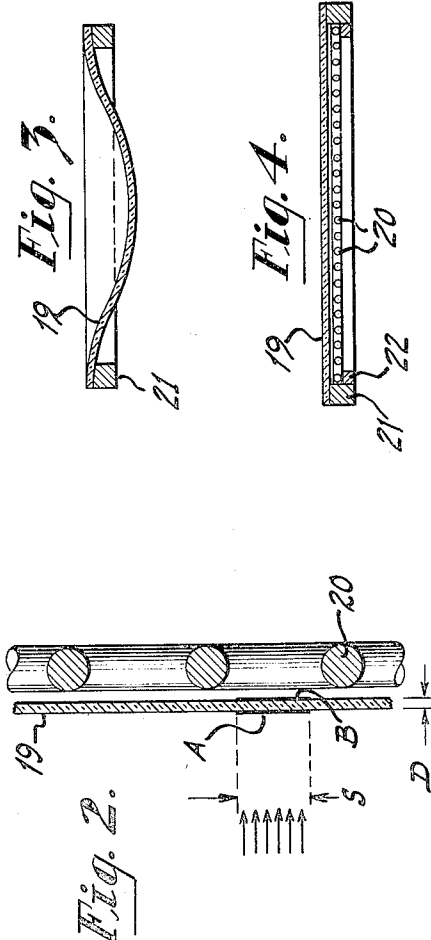
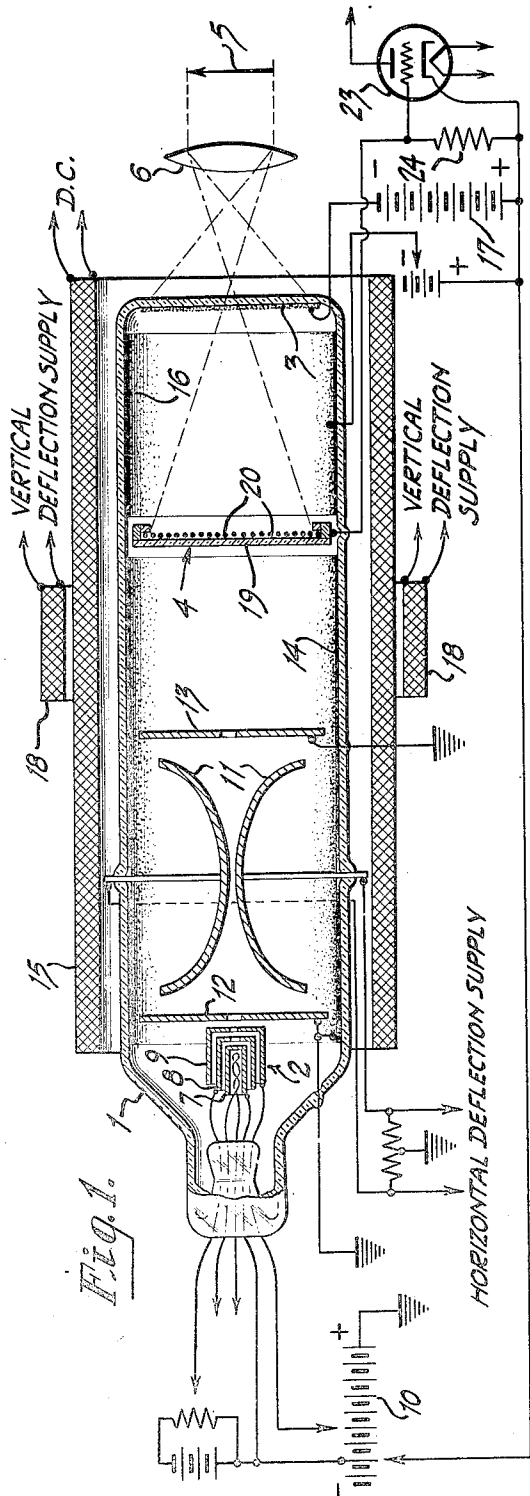
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TELEVISION TRANSMITTING TUBE

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TELEVISION TRANSMITTING TUBE

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Continuation of application Serial No. 357,543, September 20, 1940. This application November 28, 1945, Serial No. 631,441

11 Claims. (Cl. 250—167)

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My invention relates to television transmitting tubes and more particularly to tubes of the low velocity electron beam scanning and electron image types and is a continuation of my application filed September 20, 1940, Serial No. 357,543 now forfeited.

In television pick-up tubes utilizing high velocity electron beam scanning with optical or electron image projection on a surface other than the surface scanned by the high velocity beam, it has been proposed to utilize double-sided mosaic type targets, as disclosed in British Patent 442,666. Such target electrodes are exceedingly difficult to construct, the task of forming a structure having over 100,000 electrically discrete highly insulated metal plugs extending through the target and insulated from a signal screen embedded in the target being a tedious and difficult manufacturing problem. In addition, such electrodes, even though prepared with exceptional care, produce a spurious signal not representative of the electron or optical image, due to electrical or mechanical non-uniformities over the target surface.

It is an object of my invention to provide a television transmitting tube having higher sensitivity and lower distortion than tubes constructed heretofore. It is a further object of my invention to provide a television transmitting tube having low velocity electron beam scanning which is capable of exceptionally high sensitivity with substantial elimination of all spurious signals, and it is a still further object to provide such a tube and target structure therefor which is easy to manufacture.

In accordance with my invention I provide an imperforate homogeneous target of electrically semi-conducting or semi-insulating material which is very thin in comparison with the electron beam diameter or picture element size, and a signal screen very closely adjacent thereto. Further in accordance with my invention, I scan one side of the target with an electron beam preferably of low velocity and provide means to form an electrostatic image representative of the optical image to be transmitted on the opposite side of the target. These and other objects, features and advantages of my invention will be apparent when taken in connection with the following description and accompanying drawing, in which:

Fig. 1 is a longitudinal cross-sectional view of a television transmitting tube made in accordance with my invention;

Figs. 2 and 3 are views of a portion of the electrode structure shown in Fig. 1; and

Fig. 4 is a greatly enlarged sectional view of a

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portion of the target structure and associated signal screen shown in Figs. 1 and 3.

Referring specifically to my tube structure shown in the drawing, the tube comprises an evacuated envelope 1 enclosing at one end an electron gun structure 2 and at the opposite end a semi-transparent photocathode 3 of the conventional type with a target electrode 4 intermediate the electron gun and photocathode, positioned to be scanned on one side by an electron beam from the electron gun and to have an electrostatic image formed on the opposite side. This electrostatic image may be formed on the rear surface of the target 4 by projecting light, such as represented by the object arrow 5, through the lens 6 upon the photocathode 3 to liberate electrons therefrom, or the light may be projected directly upon the rear surface of the target in accordance with one modification of my teaching.

The electron gun assembly is preferably of the low velocity electron beam generating type, as described in my Patent 2,213,174, August 27, 1940, and comprises a cathode 7 from which electrons may be drawn, control electrode 8 connected to the usual biasing battery and an anode 9 provided with a beam limiting aperture through which electrons may be directed toward the target 4, the anode 9 being maintained at a positive potential with respect to the cathode by a battery or potential source 10.

Intermediate the electron gun 2 and the target 4 I provide a pair of deflection plates 11 which are curved to produce a uniformly increasing and decreasing electrostatic deflection field, a pair of shield plates 12—13, one on either side of the deflection plates 11 having slots for the passage of the electron beam, and a conductive wall coating 14. The plates 11 are connected to a source of deflection potential and to the shield plates 12—13 and coating 14, through a center-tapped resistance of 1 to 10 megohms. To produce the desired deflection and focus of the electron beam I provide means to wholly immerse the deflection plates in a uniform magnetic field which is preferably generated by a magnetic coil 15 of slightly larger diameter than the envelope 1 extending over and beyond the space between the electron gun 2 and target 4. In the embodiment of my invention shown in Fig. 1 the coil 15 preferably extends beyond the photocathode 3 to focus electrons from the photocathode upon the rear surface of the target 4, although an auxiliary short coil may be used between the photocathode 3 and target 4. The electrons from the photocathode 3 are accelerated by an electrostatic field such as

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generated by the wall coating 16 operated at a positive potential with respect to the cathode 3 by a battery or other potential source 17.

Deflection of the electron beam in a direction normal to that produced by the plates 11 is accomplished by a pair of deflection coils 18. This deflection is preferably the frame or vertical deflection, since in standard television systems the frame deflection is of lower frequency than the horizontal line deflection, the coils 18 therefore being operated at the lower of the two frequencies. The deflection coils 18 may, of course, be replaced by a second pair of deflection plates and, in fact, any other type of electron gun and associated deflection structure capable of resolving an electron beam having a velocity approaching zero adjacent the target may be used in the place of those described.

In accordance with my invention the target comprises a very thin imperforate target sheet 19 of homogeneous electrically semi-conducting material, the properties of which will be discussed in considerable detail later, supported as shown in Fig. 1 in a plane normal to the longitudinal axis of the envelope 1 and consequently normal to the projected electron beam. Closely associated with the target sheet 19 of semi-conducting material and preferably adjacent the rear surface of the sheet I provide a signal screen 20 coextensive with and very closely spaced with respect to the rear surface of the semi-conducting sheet. The enlarged fragmentary section of Fig. 2 shows the target sheet 19 and closely associated signal screen 20 with the electron beam having an elemental picture area diameter S focused on the scanned or front side of the sheet 19, this area of focus being represented by A. A corresponding area on the opposite or rear surface of the sheet 19 is designated B. The thickness D of the sheet 19 is preferably less than half the diameter of an elemental picture area, that is, less than half the diameter S of the electron beam.

The target sheet 19, as indicated above, is of semi-conducting material and I have found that the specific resistance of the material used should lie within the range of 10^9 to 10^{12} ohm-centimeters. Preferably an exceptionally thin homogeneous sheet of vitreous material such as glass, having the desired specific resistance and being smooth and of uniform thickness may be used. I have found that a thin sheet of glass known in the art as G-8 glass has the desired specific resistance of approximately 5×10^{10} ohm-centimeters and that this glass may be formed in very thin films.

In constructing this portion of my structure the glass may be blown to form a very thin glass film which is laid upon a metal supporting ring 21, whereupon it will appear as shown in Fig. 3, bulging downwardly at the center. The ring 21 is then placed in a furnace very carefully and carefully heated until the glass film is in a semi-molten state, whereupon by surface tension the bulging sheet of glass contracts to form a substantially plane surface. The wire mesh signal screen 20 is then assembled in very close proximity to the sheet 19 such as by a slip ring construction shown in Fig. 4, wherein the metal ring 22 supports the signal screen 20. I have made such assemblies wherein the thickness of the sheet of glass is less than 0.0002", which is less than one-fourth the thickness of mica usually used for high resistance types of mosaic electrodes. Following the assembly of the semi-

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insulating sheet 19 and signal screen 20, these parts are supported in the tube as shown in Fig. 1 and an electrical connection made from the signal screen to a translating device such as the thermionic tube 23 and to the positive terminal of the potential source 17 through an output impedance 24 and thence to the battery 10 at a point substantially equal to or slightly positive with respect to the potential applied to the cathode 7. The wall coating 16 is shown connected through an auxiliary potential source to maintain this coating slightly negative with respect to the signal screen 20, although these electrodes may be operated at the same potential.

In operation, high velocity electrons representative of an electron image of the picture to be transmitted are focused on the rear surface of the thin target sheet 19 to form a positive electrostatic image on this rear surface by secondary electron emission. One picture element of this electrostatic image will be formed on the area B. Other methods of forming a positive electrostatic image on the target sheet 19 may be utilized, such as by scanning the rear surface of the sheet with a modulated high velocity electron beam or by providing a discontinuous coating of cesium or other light-sensitive material on the rear surface of the sheet which, by emission of photo-electrons, forms an electrostatic image consisting of positive charges representative of the optical image to be transmitted. Thus, in the latter case the light from the object 5 may be focused directly on the rear surface of the target sheet 19, as also shown in Fig. 1. The opposite or front surface of the target sheet 19 is then scanned with an electron beam, preferably of low velocity, whereupon areas such as the area A opposite a positively charged area B receive electrons from the beam.

Referring to Fig. 2 and considering this mode of operation in more detail, assume the absence of an electrostatic image on the rear surface of the target sheet and consequently zero charge on the area B. The scanning beam such as the beam of low velocity electrons charges the elemental picture area A in a negative direction to cathode potential so that no further electrons from the beam can be collected over the area A and they return toward the gun and are collected by electrode 12, as in the above-mentioned patent and my joint Patent 2,213,175, August 27, 1940, and no signal is transmitted to the signal screen 20. Now, let picture electrons such as from the cathode 3 be projected on the surface of the sheet 19 opposite A and over the area B at such a velocity as to charge it positively by secondary emission. The charge on B may be stored continuously by making the signal screen 20 sufficiently positive with respect to the photocathode 3 to collect the secondary emission on the signal screen 20. Since the area B is positive, the space around B and including an area of the signal screen 20 will also be positive by electrostatic influence. Points very near B will have almost the same potential as B and, in particular, the area A directly opposite B and on the scanned side of the target sheet 19 will have almost the same potential as area B. A portion of the electrons of the scanning beam in passing over the area A will therefore be able to land and deposit enough charge to reduce the potential on the area A to the potential of the cathode 7. During the subsequent frame time and prior to the next scanning of the area A by the electron beam, the positive charge at B and the negative

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charge at A unite by conduction through the sheet of semi-conducting material to return both areas A and B to their original uncharged states. Assuming the proper selection of specific resistance for the material of sheet 19, very little transverse redistribution of the charges from area to area of the target will result. If, however, the specific resistance of the material is too high, such as 10^{13} ohm-centimeters or more, the neutralization of the charges on opposite sides of the sheet 19 is not completed by conduction during a single frame time, and the electrostatic picture side or rear surface of the sheet 19 will tend to charge up to the signal screen potential. However, if the semi-conducting material is chosen with the proper specific resistance, a positive charge on area B will be neutralized by the negative charge on area A during a single frame period.

Further in accordance with my invention, I have found that four conditions should be satisfied if the semi-conductor is to operate efficiently to transmit a well-defined television picture with adequate signal strength and without spurious effects. In the first place, the period of discharge between the two sides of the target sheet should be equivalent to the frame time. Secondly, the capacitance between the two surfaces of the semi-insulator should be as great as and preferably several times greater than the capacitance between the picture side of the target and the signal screen. In terms of Fig. 2 the capacitance between the areas A and B should be several times the capacitance between B and the signal screen 20. These relationships of capacity are to insure that a reasonably large fraction of the picture charge is converted to useful picture signal. This fraction of picture charge so used is actually

$$\frac{C_{AB}}{C_{AB} + C_{B20}}$$

where C_{AB} =capacitance between areas A and B and C_{B20} =capacitance between area B and the signal screen 20. Due to the exceptionally small spacing desired between the signal screen 20 and the semi-insulating sheet 19, the capacitance between B and collecting anode 12 or any surrounding conductors other than the signal screen 20 is negligibly small. The third condition is that the thickness of the semi-insulator should be less than one-half the diameter of a picture element, and the signal screen 20 spaced less than a picture element from the nearest adjacent surface of the target sheet 19 in order to confine the electrostatic influence of a picture element on the picture side to only the corresponding element on the scanned side. The fourth condition requires that the time constant for the lateral diffusion of a picture charge should be equal to or greater than the period of frame scanning. This condition may be expressed and satisfied by the following relationship:

$$\frac{\rho EC}{\pi Dt} \geq 1$$

where

ρ =volume resistivity of target (ohm-cm.)
 E =elemental picture area (square centimeters)
 C =capacitance between picture side of target and screen (farads/cm.²)
 D =thickness of target (cms.)
 t =frame time (seconds).

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A reasonable set of values for these parameters satisfying all of the four conditions above is:

$$\begin{aligned} \rho &= 5 \times 10^{10} \text{ ohm-cms.} \\ E &= 10^{-4} \text{ square cms.} \\ C &= 10^{-10} \text{ farads/cm.}^2 \\ D &= 10^{-3} \text{ cms.} \\ t &= 1/30 \text{ sec.} \end{aligned}$$

While in the example given above I have described a tube making use of electron image projection to form the electrostatic picture image on the rear surface of the semi-insulating target, I have also mentioned that this electrostatic image may be formed by light projected directly on the rear surface, provided the surface is sensitized with caesium. However, the described electron image projection is preferred because of the larger obtainable signal.

My invention may be distinguished from the conventional double-sided type of mosaic such as the type described in my U. S. Patent 2,213,173 and U. S. Patent to Hickok No. 2,047,369, in that I provide no conductive plugs extending through and insulated from a wire mesh screen embedded in high resistance insulation such as vitreous enamel. In this type of construction it is necessary to provide exceptionally high resistance between the plugs and the embedded screen for the express purpose of preventing electrical leakage between the plugs and the screen. In my improved television transmitting tube I avoid the difficulties attendant upon the prior art structure by wholly eliminating the embedded screen and, in fact, I have found it disadvantageous to provide any good metal contact between the semi-conducting target sheet 19, which must be homogeneous, and any other electrode in the tube such as the signal screen 20. The signal screen 20 must therefore be substantially insulated from the sheet 19 so that electrical and mechanical contacts between the signal screen and the sheet 19 are a minimum.

In tubes with two-sided targets it has been proposed to place on the cathode side of the target a signal electrode in the form of a metal screen in register with or spaced from the target in the neighborhood of a millimeter, to collect the beam electrons not landing on the target to discharge the charge image on the opposite side. This is not a practical construction, since, as a result of the high capacitance between the screen and the target, the negative charges bound by the positive charges of the electrostatic image on the target are substantially all on the screen and a negligible number on elements spaced widely therefrom. When the beam lands sufficient electrons on the target through the screen to discharge the positive charges with current i , a substantially equal discharge of these previously bound negative charges passes from the screen to the signal device. This discharge current passing from the screen is substantially equal to i . The remainder of the beam collected by the screen is, of course, $I-i$. These two current components passing from the screen to the signal device are in phase. Hence the total current from the screen to the signal device is $I-i+i=I$, or the unmodulated beam. In my invention the beam electrons not landing on the screen are collected by an electrode adjacent the cathode, such as electrode 12, which is widely spaced from the target and has negligible capacitive relation therewith, while the screen electrode on the image side of the target has adequate capacitance with the elemental area being scanned by the beam to furnish a suit-

able signal. The beam returning to my collecting electrode is also modulated by this signal, as will be appreciated. In my improvement adequate signal is thus present in the separate currents of these two electrodes.

My invention is further distinguished over the prior art which utilizes a mica foundation for a mosaic electrode or any other insulation having high electrical resistance such as mica which is of the order of 10^{20} ohm-centimeters. My invention should therefore not be confused with tubes using these types of electrodes. In fact I have attempted to operate tubes of this type wherein the target consisted of a mica foundation scanned on one side by a low velocity electron beam, the electrostatic image being formed on the opposite side, and have found that such tubes will not operate with a low velocity electron beam because, after a few scans of the beam, elemental areas of the target become charged up to the secondary electron collection potential thereby preventing any further operation. With my new and improved tube, however, I have obtained from three to ten times the sensitivity usually obtained in tubes of the "orthicon" type as described in U. S. Patents 2,213,174-6, which, in turn, are from ten to fifty times more sensitive than the conventional "iconoscope" which utilizes a high velocity electron beam. Consequently, the television transmitting tubes made in accordance with my invention, when utilized in conjunction with low velocity electron beam scanning, have produced sensitivities of the order of thirty to five hundred times the sensitivity of the well-known iconoscope type of tube.

While I have indicated the preferred embodiment of my invention and have indicated the specific application as directed to cathode ray television transmitting tubes, it will be apparent that my invention is by no means limited to the purpose of television transmission and that many variations may be made in the particular structure disclosed without departing from the scope of the invention as set forth in the appended claims.

I claim:

1. A television transmitting tube comprising an evacuated envelope, a cathode within said envelope to liberate electrons, a target in the path of electrons from said cathode, said target comprising an imperforate sheet of semi-conducting material, means to focus the liberated electrons over a picture element area on one side of said target, means to scan said beam over said target so that elemental areas thereof are repetitively scanned at a predetermined frame rate of scanning and a signal screen electrode spaced at a finite distance from and coplanar with said target, the parameters, E , D , ρ and C having such value that

$$\frac{\rho EC}{\pi Dt} = 1$$

where E is the picture element area in square centimeters, D the thickness of the target in centimeters, ρ the volume resistivity of the target in ohm-centimeters, C the capacitance between the nearest adjacent surface of the target and said signal screen electrode in farads per square centimeter and t is the frame time of scanning in seconds.

2. A television transmitting tube comprising an evacuated envelope, a cathode within said envelope to liberate electrons, an apertured anode to form an electron beam, a target facing

said cathode of electrically semi-conducting material having a specific resistance less than 10^{13} ohms-centimeters, means to focus said electron beam over a picture element area on said target, means to sweep said beam over said target, a signal screen electrically separated from and closer to said target than the diameter of said picture element, and means including a photocathode to form an electrostatic image on the surface of said target opposite that facing said cathode.

3. A television transmitting tube comprising an evacuated envelope, means to generate an electron beam of picture element diameter, a target having one surface adapted to be scanned by said beam, said target consisting of a thin homogeneous imperforate sheet of material having a specific resistance between 10^{10} and 10^{13} ohm-centimeters, means to project said electron beam on said target with a velocity approaching zero at the surface of said target, an electron permeable signal screen electrode coplanar with and separated from one surface of said sheet by a finite distance less than said picture element diameter, and means including a photocathode to generate on the side of said target opposite said surface adapted to be scanned by the beam an electrostatic image representative of the image to be transmitted.

4. A television transmitting device comprising a tube having an evacuated envelope, means within said envelope adapted to generate a beam of electrons having low electron velocity, a target comprising a sheet of electrically semi-conducting material, means for producing a uniform magnetic focusing field for said electrons, both surfaces of said sheet being exposed over the entire picture area within said envelope, a signal screen closely adjacent one exposed surface of said target and substantially parallel therewith, means to scan said electron beam over one exposed area of said target and means including a photo-cathode to develop an electrostatic image of the picture to be transmitted over the other exposed area of said target.

5. A television transmitting tube comprising an evacuated envelope, an electron gun to develop an electron beam, a homogeneous imperforate target of material having a specific resistance of 10^9 to 10^{13} ohm-centimeters in the path of said beam, means to scan said beam over elemental areas on one side of said target, an electron permeable signal screen closely adjacent said target, the thickness of said target being sufficiently small that the capacitance between elemental areas on opposite sides of said target is greater than the capacitance between said signal screen and the one of said areas nearest adjacent the said signal screen, and means to develop an electrostatic image representative of the picture to be transmitted on the side of said target opposite the side scanned by said beam.

6. A television transmitting device comprising a tube having an evacuated envelope, a target in said tube consisting of a thin homogeneous sheet of electrically conducting vitreous material, an electron gun to develop a beam of electrons, means surrounding said envelope to produce a magnetic field to direct and focus said beam on said target, means to scan said beam over one continuous exposed surface of said vitreous material target, a foraminous signal electrode coextensive with and uniformly spaced from the continuous exposed surface of

said target opposite that scanned by said beam, and means including a photo-cathode to generate an electrostatic image of the picture to be transmitted on the surface of said target adjacent said signal electrode.

7. A television cathode ray transmitting tube comprising a cathode, a target consisting of a thin sheet of semi-conducting material positioned with one surface facing said cathode, means including a photo cathode for forming an electrical charge image on elemental areas of the opposite surface of the target, means for projecting a beam of electrons from said cathode toward points adjacent said elemental areas with a velocity approaching zero thereat, means for focusing the electrons of said beam on said points, an electrode on the image side of the target having substantial capacitative relation with said elemental areas, means for scanning said beam over said points with loss of electrons thereto proportional to the charges on the image surface of the target, a collecting electrode for the remainder of the beam electrons having negligible capacitative relation with said target, and connections for utilizing the current flowing from one of said electrodes.

8. A television cathode ray transmitting tube comprising a cathode, a target consisting of a thin sheet of semi-conducting material positioned with one surface facing said cathode, means including a photo cathode for forming an electrical charge image on elemental areas of the opposite surface of the target, means for projecting a beam of electrons from the first-mentioned cathode to elemental areas of the first-mentioned surface of the target with a velocity approaching zero thereat, means for focusing the electrons of said beam on the last-mentioned elemental areas, an electrode adjacent said target having substantial capacitative relation with the first-mentioned elemental areas, means for scanning said beam over the target to land part of the electrons of the beam for discharging said image by passage through the target, a collecting electrode for the remainder of the beam electrons having negligible capacitative relation with said target and connections for utilizing the current flowing from one of said electrodes.

9. A television cathode ray transmitting tube comprising a cathode, means for producing a uniform magnetic focusing field in said tube, a target consisting of a thin sheet of semi-conducting material positioned in said field with one surface facing said cathode, means including a photo cathode for forming an electrical charge image on the other surface of the target, an electrode on the image side of the target having substantial capacitative relation therewith, means for projecting a beam of electrons from the first mentioned cathode to points adjacent the image surface of the target with a velocity approaching

zero thereat, means for scanning said beam over said points with loss of electrons thereto proportional to the charges on the image surface of the target, a collecting electrode for the remainder of the beam electrons positioned in said field and having negligible capacitative relation with said target, and connections for utilizing the current flowing from one of said electrodes.

10. A television cathode ray transmitting tube comprising a cathode, means for producing a uniform magnetic focusing field in said tube, a target consisting of a thin sheet of semi-conducting material positioned in said field with one surface facing said cathode, means including a photo cathode for forming an electrical charge image on the other surface of the target, an electrode adjacent said target having substantial capacitative relation therewith, means for projecting a beam of electrons from said first-mentioned cathode to the target with a velocity approaching zero thereat, means for scanning said beam over the target to land part of the electrons of the beam for discharging said image by passage through the target, a collecting electrode for the remainder of the beam electrons positioned in said field and having negligible capacitative relation with said target, and connections for utilizing the current flowing from one of said electrodes.

11. A television cathode ray transmitting tube comprising a thermionic cathode, means for producing a uniform magnetic focusing field in said tube, a target consisting of a thin sheet of semi-conducting material positioned in said field with one surface facing said cathode, means including a photo cathode for forming an electrical charge image on the other surface of the target, an electrode on the image side of the target having substantial capacitative relation therewith, means for projecting a beam of electrons from said thermionic cathode to the target with a velocity approaching zero thereat, means for scanning said beam over the target to land part of the electrons of the beam for discharging said image by passage through the target, a collecting electrode for the remainder of the beam electrons having negligible capacitative relation with said target, and connections for utilizing the current flowing from one of said electrodes.

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