

Nov. 24, 1959

J. R. ESHBACH
ELECTRON BEAM DEVICE

2,914,696

Filed May 31, 1957

2 Sheets-Sheet 1

Fig. 1.

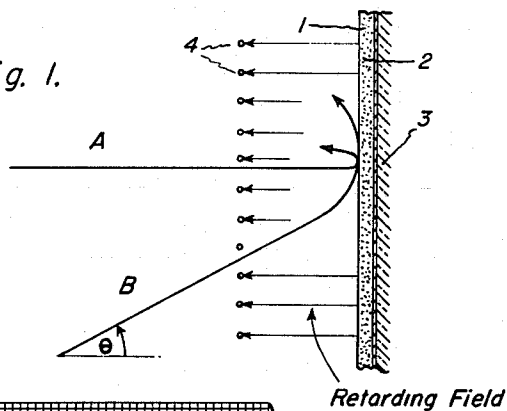
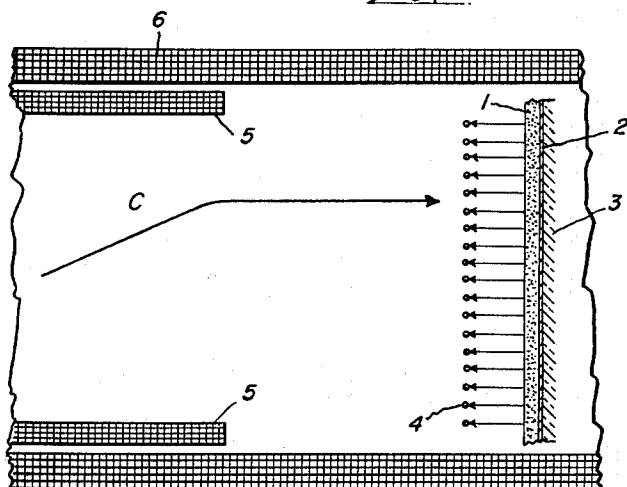


Fig. 2.

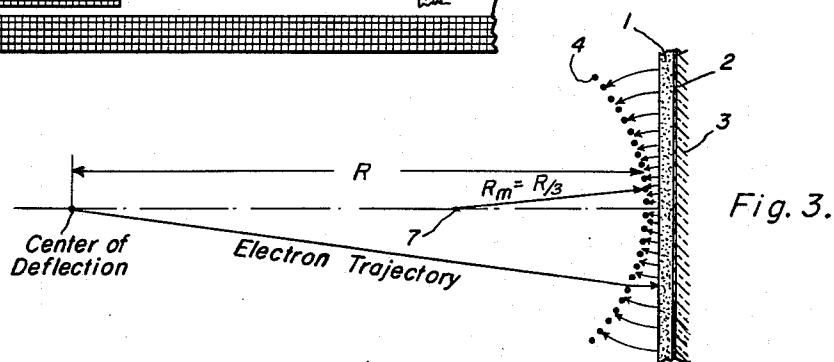


Fig. 3.

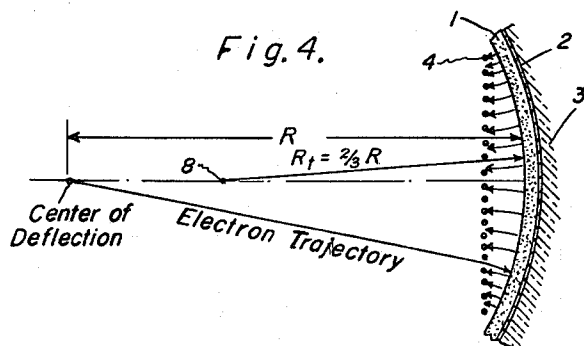


Fig. 4.

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2 Sheets-Sheet 2

Fig. 5.

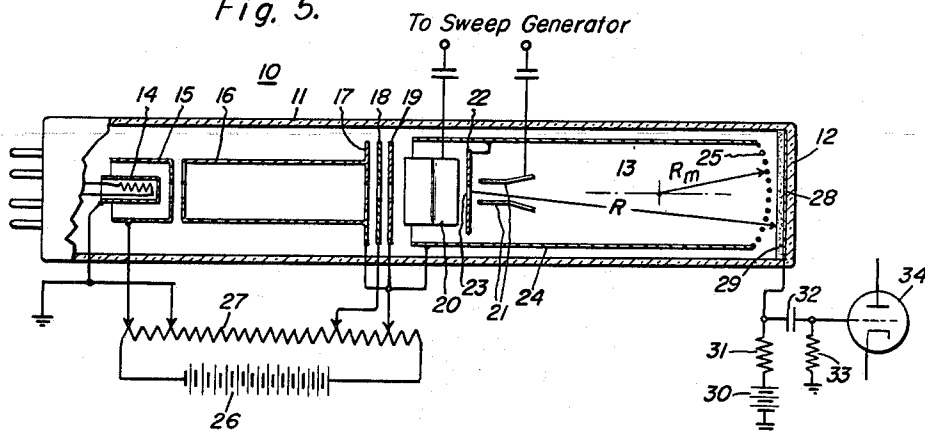
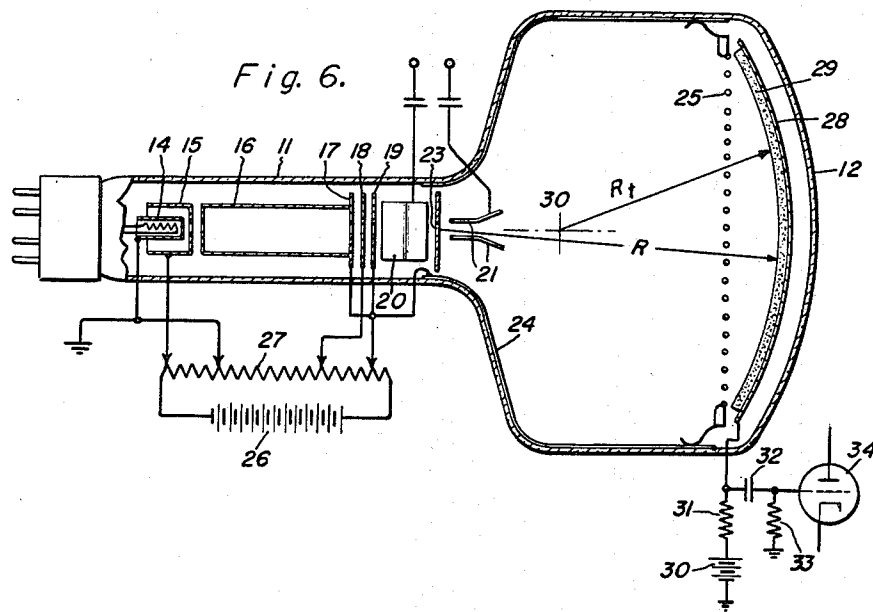


Fig. 6.



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2,914,696

ELECTRON BEAM DEVICE

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5 Claims. (Cl. 315-10)

The present invention relates to electron beam image transcribing devices. Some examples of devices of this nature are television camera tubes and X-ray camera tubes.

In devices of this nature an electron beam scans an insulating or semiconductive target screen and thereby may deposit an electrical charge upon the target surface. If the target surface is scanned at high electron velocities, the target surface potential may rise to a value higher than the cathode potential, due to a secondary electron emission ratio of greater than unity. This mode of operation is denominated as "high velocity scanning." This mode of operation has the advantage that the potential of the target surface is independent of the angle of beam incidence. High velocity scanning is disadvantageous, however, in that under this mode of operation, secondary electron emission causes undesirable non-uniform effects over the target surface, and that high velocity bombardment damages the target surface.

The disadvantages of high velocity scanning may be overcome by low-velocity scanning. In this mode of operation, the secondary electron emission ratio at the target surface is maintained less than unity and the target surface potential approaches the potential of the cathode. The characteristics of low-velocity scanning in electron beam tubes of this nature is described in an article by Iams and Rose, appearing in Proc. IRE, 27, 547 (1939). A television camera tube constructed to utilize this mode of operation is disclosed in U.S. Patent 2,710,813 to S. V. Forgue. In essence, low velocity scanning is achieved by accelerating the electron beam to moderately high velocities and then passing the beam through a retarding or decelerating field immediately before impingement upon the target to reduce the electron velocities to a value which maintains the secondary emission ratio of the target less than unity. This retarding field is achieved by maintaining the target electrode at a potential which is low with respect to the beam accelerating potential.

Electron beam image transcribing devices utilizing low velocity scanning operate under the requirement that the scanning beam must impinge normally upon the target surface in all places. In order to satisfy this requirement, devices of the prior art require long solenoidal coils to establish a longitudinal magnetic field which encompass substantially the entire beam-traversed volume from the cathode to the target. Additionally, the electromagnetic deflection coils utilized must be of a length which constitutes a large fraction of the beam traverse distance. Such coils are expensive, cumbersome, and require well regulated currents.

Accordingly, an object of the present invention is to provide an electron beam image transcribing device suitable for operation with low velocity scanning and which may utilize simple localized electron beam deflection.

Another object of the invention is to provide a low-velocity-scanning electron beam image transcribing de-

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vice which does not require for its operation an axial magnetic field.

A further object of the present invention is to provide a low velocity scanning camera tube utilizing localized beam deflection.

In accord with one embodiment of the present invention, I provide an improved electron beam image transcribing tube utilizing low velocity scanning and having an electron gun for producing a focused beam of electrons, a localized beam deflection means which may be either electrostatic or electromagnetic, a target-adjacent mesh electrode and a target electrode. Either one or both of the mesh electrode and the target electrode are spherical segments. The voltages applied to these elements, together with their geometry, produce a non-uniform electric field configuration therebetween which causes electrons emanating from a point center of deflection to impinge upon the target normally at all points.

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may best be understood with reference to the following description taken in connection with the drawing in which;

Figures 1, 2, 3 and 4 are diagrams of electron trajectories in devices with which the present invention is concerned;

Figure 5 is a schematic drawing of an image transcribing tube constructed in accord with one embodiment of the invention; and

Figure 6 is a schematic drawing of another embodiment of the invention.

In Figure 1 of the drawing, there is represented schematically the region adjacent the target surface of an image transcribing tube of the type with which the present invention is concerned. In Figure 1, a semiconducting target layer 1, backed with a conductive layer 2 is mounted upon a radiation transparent insulating substrate 3. A conducting mesh or grid 4 is interposed parallel with and adjacent the target layer 1 between the target and a source of electrons, not shown. A voltage V_m is applied to mesh 4, and a voltage V_t negative with respect to V_m is applied to the conducting layer behind the target surface. Since the target and mesh are parallel, the electric field therebetween is uniform. When an electron is projected normally through mesh 4 to target surface 1 in a line A, at the time the electron passes through mesh 4, it possesses an energy eV_m . Assuming that the electric field between semiconducting surface 1 and mesh 4 is just sufficient to cause the electron to be reflected from the target surface, the target surface then will have a potential V_s at the point from which the electron is reflected, of zero. This is the general case in image tubes of the low velocity scanning type. Under unexcited conditions the target surface assumes a potential of zero with respect to the cathode. If an electron is projected through mesh 4 onto target surface 1 at an angle θ with respect to the normal, in path B, at the time the electron is just reflected from target surface 1, it has no velocity normal to the surface, but has a tangential velocity. Thus, the point from which the electron is reflected will have a potential of $V_m \sin^2 \theta$. If V_m has a value of approximately 300, as is normal in devices of this type, it may readily be seen, therefore, that the variation in potential across the target surface from normally incident electrons to large-angle incident electrons will vary greatly, particularly for large values of θ , thus rendering the operation of devices of this type extremely unreliable.

In Figure 2 of the drawing there is shown the prior art expedient by which normal incidence of electrons has been assured under low-velocity scanning conditions. An

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electron stream is directed against the target surface and caused to pass through mesh 4. However, rather than using localized deflection as in Figure 1, the devices of the prior art utilize extended deflection coils 5 in connection with a long solenoidal coil 6 to establish a longitudinal magnetic field. These coils cause electrons to traverse a path indicated at C. This insures that all electrons, irrespective of angle of deflection, impinge upon the target surface at normal incidence.

As is mentioned hereinbefore, although the expedient illustrated schematically in Figure 2, is sufficient to cause all electrons to be normally incident upon the target surface, the provision of a long solenoidal coil which entirely encloses the discharge device from cathode to target is cumbersome, expensive and requires well regulated currents.

In accord with the present invention, I combine the advantages of high velocity scanning, namely the feasibility of utilizing localized deflection of the electron beam, with the advantages of low velocity scanning, namely the absence of uneven secondary emission effects, damage from high velocity electrons, etc. In accomplishing these results I utilize a conventional cathode gun to form a beam of electrons. The beam of electrons is then deflected, as for example in a raster scan, by localized deflection means, either electrostatic or electromagnetic. As utilized herein "localized deflection means" is used to connote electrostatic deflection plates or magnetic deflection yokes the lengths of which are very small with respect to the beam-traverse distance. The beam then passes through a high potential target-adjacent mesh electrode and impinges upon a low potential target surface in close proximity to the decelerating mesh. As utilized herein the requirement that the mesh electrode and the target be in close proximity is intended to connote that the distance between the two electrodes is very small with respect to the beam-traverse distance. The relationship of the target surface to the mesh electrode is such that one or both of these members comprise spherical segments with center of curvature located between cathode and target, so that the two surfaces are generally not parallel. This results in a non-uniform electric field between the two surfaces. The non-uniform electric field between the two surfaces acts upon the electron passing through that region to modify the electron trajectories so that all electrons impinge normally upon the target surface. In general, the optimum operation of devices constructed in accord with the present invention is achieved when the following mathematical relationship is satisfied in the geometry of the tube:

$$\frac{1}{R} = \frac{1}{3R_m} + \frac{2}{3R_t}$$

where

R = the deflection radius, i.e., the normal distance from the target surface to the center of deflection

R_m = the radius of curvature of the mesh electrode

R_t = the radius of curvature of the target surface

When the above equation is satisfied, the problems inherent in localized deflection in a low velocity scanned device are substantially eliminated. When the conditions are approximated closely, these problems are minimized.

In Figures 3 and 4 of the drawing, there are shown two specific cases in which Equation 1 is satisfied. In Figure 3, target 1 has zero curvature and is planar while mesh 4 is a spherical segment with its center of curvature at 7. Applying Equation 1, since the radius of curvature of the planar target is infinite, the target term vanishes and for optimum operation, the radius of curvature of the mesh electrode should be one-third the deflection radius, which is the normal distance from the center of deflection to the target.

In Figure 4 there is illustrated another specific example in which the target 1 is a spherical segment with its center

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of curvature 3, located between cathode and target and mesh 4 is planar and has zero curvature. In this instance, since the radius of curvature of the mesh is infinite, the mesh term in the equation vanishes, and for optimum operation, the radius of curvature of the target should be two-thirds the deflection radius, which is the normal distance from the center of deflection to the target surface.

Although the examples illustrated by Figures 3 and 4, described above, are two conditions in which tubes constructed in accord with the present invention may be constructed, it will be appreciated that there are an infinite number of configurations in which both target surface and mesh electrode are spherical with centers of curvature between target and cathode, and satisfy, or approximate, Equation 1 above, to provide non-uniform electric field therebetween which modifies the trajectories of locally deflected electrons to cause normal incidence upon the target surface over the entire face of the tube.

In Figure 5 of the drawing, there is illustrated a photoconductive television camera tube 10 constructed in accord with one specific embodiment of the invention. Image tube 10 comprises an evacuable envelope 11, which may be cylindrical, having a transparent faceplate 12. At the end of envelope 11 opposite faceplate 12 there is located a conventional electron gun assembly for producing a focused beam of electrons including an indirectly heated cathode 14, a beam control electrode 15, and a first accelerating anode 16 having a flanged anterior member 17, which together with members 18 and 19 comprise an electron lens for focusing the electron beam. Immediately after the electron lens, are located a pair of horizontal deflection plates 20 and a pair of vertical deflection plates 21 separated by a field isolation plate 22 having an aperture 23 therein. Aperture 23, in the center of plate 22, which is located between deflection plates 20 and 21, comprises the center of deflection for the tube. While electrostatic deflection plates are shown herein, it is apparent that localized electromagnetic scanning, such as frequently utilized in kinescopes, may be utilized as well.

A cylindrical accelerating electrode 24 completely encircles the beam traverse region of the tube extending from the deflection plates to immediately prior to faceplate 12 and is terminated in a wire or like mesh electrode 25. Mesh electrode 25 is a spherical segment with center of curvature at 13. A retarding electric field exists between mesh 25 and the target electrode for reducing the velocity of the electron beam before striking the target to maintain the secondary emission ratio less than unity. As is discussed hereinbefore, with respect to Figure 3, for optimum operating results, the radius of curvature of mesh electrode 25 should be approximately one-third the deflection radius of the tube. Cylinder 24 may conveniently comprise a conductive carbonaceous coating upon the interior surface of evacuable envelope 11. On the interior surface of faceplate 12 of tube 10 there is deposited a transparent conducting target electrode 28 which may conveniently be tin oxide or reduced titanium dioxide. Upon the transparent conducting electrode there is deposited a photoconducting target layer 29 which may be any material the electrical conductivity of which varies when irradiated by visible light. Such materials may conveniently be the oxides, sulfides, selenides or tellurides of zinc, cadmium or lead, having an intrinsic resistivity of approximately 10^{12} ohm centimeters or greater. Mesh electrode 25 may conveniently comprise a wire screen having apertures therein sufficiently large to allow substantially all high velocity electrons to pass therethrough but sufficiently small as to enable the electrode to cooperate with target electrode 20 to establish a beam decelerating field. Conveniently, screen 25 may comprise .002" diameter wires, approximately 100 wires per inch.

Operating potentials are supplied to the electrodes of tube 10 from a voltage source represented conveniently as battery 26, through potentiometer 27. Typical operat-

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ing potentials are as follows. Using the cathode potential as ground or reference potential, control electrode 15 may be maintained at approximately 0 to -100 volts bias to control the beam current to a suitable value. Accelerating anode 16 and second accelerating anode 24 with its associated mesh are maintained conveniently at approximately 300 volts. Element 19 of the electron lens is also conveniently maintained at 300 volts and element 18 thereof is conveniently maintained at a lower potential of approximately 200 volts. Deflection plates 20 and 21 are connected to the accelerating anodes for direct current bias and an alternating voltage is applied thereto to produce a raster scan from a conventional sawtooth generator, not shown. Element 22 is maintained at accelerating anode potential. Target electrode 28 is maintained at a potential of approximately 25 volts. The electric field established between mesh electrode 25 and target electrode 28 is sufficient to establish a non-uniform decelerating field therebetween which causes the electron beam, emanating from center of deflection 23 to impinge upon target surface 29 normally at all points.

In operation, a beam of electrons is generated at cathode 14, controlled to the proper density by control electrode 15, accelerated by first accelerating anode 16, focused to the proper diameter by the electron lens comprising elements 17, 18 and 19 and deflected in a raster pattern by deflection plates 20 and 21. Since the configuration of mesh electrode 25 and target electrode 28 is such as to cause electrons to impinge normally thereupon at all angles of incidence, the bombarded surface of target 29 approaches cathode potential and has a uniform potential over all portions thereof since the electrode potentials are adjusted to cause the electrons to impinge thereupon at velocities which establish a secondary emission ratio of less than unity. When a visible image is then incident upon the exterior surface of photoconducting layer 29 through transparent electrode 28, the conductivity of the photoconductive target is modified at discrete points in accord with the image impressed thereupon. This results in a point-by-point variation in the potential upon the electron-bombarded surface of the photoconductor. When upon the next scan of the bombarded surface of the photoconductor by the raster swept electron beam, the potential upon the bombarded surface of the photoconductor is again lowered to cathode potential at all points by the impinging electrons an equivalent electric charge flows from voltage source 30 through load resistor 31 and onto the opposite surface of the photoconductive layer in order to maintain an equal image charge thereon. The signal thus generated across resistor 31 in synchronism with the raster scan upon the surface of target 29 is coupled through capacitor 32 and resistor 33 to amplifier tube 34. The visual image impressed upon the exterior surface of photoconductive layer 29 is thereby transformed into an electrical signal which may be transmitted to a television picture tube for the presentation of a synchronous image.

One great advantage of tubes constructed in accord with the illustrated embodiment of the invention is that due to the configuration of mesh electrode 25 and target screen 29, locally deflected electrons are caused to impinge normally upon screen 29, irrespective of the angle of exit through screen 25. Because of this it is unnecessary to provide a large axial magnetic deflection field encompassing the entire space between the cathode and target electrode. Thus, the tube constructed in accord with this embodiment of the invention is simpler and easier to operate, but yet produces results comparable to conventional camera tubes which are much more complicated and expensive to manufacture.

In Figure 6 of the drawing, there is illustrated another specific embodiment of the invention. In the tube of Figure 6, the target comprises a spherical segment with center of curvature at 30, and the mesh electrode is planar, the opposite of the arrangement illustrated in Fig-

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ure 5. The non-uniform electric field established between these two elements has the same effect as in the device of Figure 6, namely to cause locally deflected electrons to impinge upon the screen normally for all angles of deflection. In this embodiment, as is set forth with respect to Figure 4 of the drawing, for ideal conditions the ratio of the radius of curvature of the target surface to the deflection radius R_t/R is approximately two-thirds. The electron gun of the device of Figure 6 is essentially the same as that of the device of Figure 5 and like reference numerals indicate like elements. The target area of the device of this embodiment is, however, substantially larger in diameter than the diameter of the electron gun portion of the tube. This particular configuration is ideally adapted for X-ray camera pickup applications. In accord with the particular use to which it is adapted, it is not necessary that the target area be planar since any slight distortion which may be introduced in portraying a planar object is not particularly deleterious in X-ray photography. Such distortion may, however, be eliminated by utilizing a non-linear rather than a sawtooth generator to actuate the deflection plates. Operating potentials for the device of Figure 7 may typically be the same as those for the device of Figure 6 with the sole exception that the target electrode is generally maintained at a higher potential of, say, approximately 100 volts. If the device of Figure 7 is to be utilized as an X-ray image tube, conducting electrode 28 need only be transparent to X-rays and may be a thin metallic sheet upon which layer 29 is supported.

Both of the devices of Figures 5 and 6 are of the type, and operate upon the general principles of, the vidicon-type camera tube, wherein a photoconductive screen is scanned by a constant intensity cathode ray beam and images in visible light directed upon the photoconductive surface are translated into an electrical signal synchronized with the raster scan applied to the cathode ray beam. In the vidicon-type image tube this is accomplished by the effect of incident light upon the photoconductive target surface. The principle of the present invention is, however, equally applicable to orthocon and image orthocon-type tubes wherein a photoemissive surface is utilized rather than a photoconductive surface. In general, devices in accord with the invention may be constructed for any use in which a locally deflected cathode ray beam scans an extended area photosensitive surface and it is essential that the electrons comprising the beam be incident upon the target electrode normally for all angles of deflection.

While the invention has been set forth herein with respect to specific embodiments thereof, many changes and modifications will immediately occur to those skilled in the art. Accordingly, I intend by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A low voltage scanning electron beam transcribing device comprising an evacuable envelope having a faceplate at one end thereof; an electron gun for producing a focused beam of electrons at the opposite end of said envelope; localized deflection means for locally deflecting said electron beam to form an extended area scanning pattern; a positively biased accelerating electrode substantially entirely laterally surrounding the free travel path of said electron beam, said accelerating electrode being electrically connected to a mesh electrode interposed in the path of said electron beam in close proximity to said faceplate; a radiation transparent electrically conductive target electrode immediately interior of said faceplate; a photosensitive layer upon the electron-beam-scanned surface of said target electrode, at least one of said mesh electrode and said target electrode being a spherical segment; concave with respect to said electron gun; means applying a predetermined accelerating poten-

tial to said mesh electrode; and means applying a predetermined decelerating potential to said target electrode, said potentials being correlated to produce a non-uniform decelerating electric field between said mesh and target electrodes effective to cause substantially all electrons incident upon said target to arrive thereat with normal incidence and substantially zero velocity.

2. A low voltage scanning electron beam transcribing device comprising an evacuable envelope having a faceplate at one end thereof; an electron gun for producing a focused beam of electrons at the opposite end of said envelope; localized deflection means for locally deflecting said electron beam to form an extended area scanning pattern; a positively biased accelerating electrode substantially entirely laterally surrounding the free travel path of said electron beam, between said deflection means and said faceplate; beam trajectory modifying means comprising a mesh electrode and a radiation transparent electrically conductive target electrode in the order named along said beam path for modifying the trajectory of locally deflected electrons comprising said beam to cause said electrons to impinge normally upon said target electrode at all deflection angles, said mesh electrode being electrically connected with said accelerating electrode, at least one of said last named electrodes comprising a spherical segment concave with respect to said electron gun; a photosensitive layer deposited upon the interior surface of said target electrode; means applying a predetermined accelerating potential to said mesh electrode; and means applying a predetermined decelerating potential to said target electrode, said potentials being correlated to produce a non-uniform decelerating electric field between said mesh and target electrodes effective to cause substantially all electrons incident upon said target to arrive thereat with normal incidence and substantially zero velocity.

3. An electron beam transcribing device comprising an evacuable envelope having a faceplate at one end thereof; an electron gun for producing a focused beam of electrons at the opposite end of said envelope; localized deflection means for locally deflecting said electron beam to form an extended area scanning pattern; a positively biased accelerating electrode substantially entirely laterally surrounding the free travel path of said electron beam between said deflection means and said faceplate; a mesh electrode and a radiation transparent electrically conductive target electrode interposed in close proximity along the beam path in the order named, said mesh electrode being electrically connected with said accelerating electrode, the curvature of said last two mentioned electrodes being defined by the relationship

$$\frac{1}{R} = \frac{1}{3R_m} + \frac{2}{3R_t}$$

where

R = the deflection radius of the device

R_m = the radius of curvature of the mesh electrode

R_t = the radius of curvature of the target electrode

and a photosensitive layer deposited upon the electron-beam-bombarded surface of said target electrode.

4. An electron beam transcribing device comprising an evacuable envelope having a faceplate at one end thereof; an electron gun for producing a focused beam of electrons at the opposite end of said envelope; localized deflection means for locally deflecting said electron beam to form an extended area scanning pattern; a positively biased accelerating electrode surrounding the free travel path of said electron beam, said accelerating electrode being electrically connected to a mesh electrode interposed in the path of said electron beam in close proximity to said faceplate; a substantially planar radiation transparent, electrically conductive target electrode interior of said faceplate; and a photosensitive layer upon the electron beam bombarded surface of said target electrode, said mesh electrode being a spherical segment, the curvature of which is approximately defined by the equation

$$R = 3R_m$$

where

R = the deflection radius of the device and

R_m = the radius of curvature of the mesh electrode

5. An electron beam transcribing device comprising an evacuable envelope having a faceplate at one end thereof; an electron gun for producing a focused beam of an electron at the opposite end of said envelope; localized deflection means for locally deflecting said electron beam to form an extended area scanning pattern; a positively biased accelerating electrode substantially entirely laterally surrounding the free travel path of said electron beam, said accelerating electrode being electrically connected to a substantially planar mesh electrode interposed in the path of said electron beam; and a radiation-transparent, electrically-conductive target electrode interior of said faceplate, said target electrode comprising a spherical segment, the radius of curvature of which is defined by the relationship

$$\frac{1}{R} = \frac{2}{3R_t}$$

where

R = the deflection radius of the device and

R_t = the radius of curvature of the target electrode

and a layer of a photoconductive material deposited upon the radiation scanned surface of said target electrode.

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