

United States Patent

Miyashiro et al.

[15] 3,702,410

[45] Nov. 7, 1972

[54] **IMAGE PICKUP TUBE
SEMICONDUCTOR TARGET SUPPORT
STRUCTURE**

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[22] Filed: April 20, 1971

[21] Appl. No.: 135,710

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 889,756, Dec.
31, 1969, abandoned.

[30] **Foreign Application Priority Data**

Jan. 7, 1969 Japan44/1181
Feb. 7, 1969 Japan44/8697
April 2, 1969 Japan44/25425

[52] U.S. Cl.313/66, 313/82, 313/285

[51] Int. Cl.H01j 31/28, H01j 29/02, H01j 31/38

[58] Field of Search.....313/65 A, 66

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Primary Examiner—Robert Segal
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[57] **ABSTRACT**

An image intensifier vidicon which is divided by a semiconductor target into an image section, the inner surface of the face plate of which is coated with an electron-emissive layer and a scanning section, wherein said semiconductor target includes a semiconductor substrate, a plurality of PN junctions formed therein, an accelerating layer formed on the electron incident side of said target, and a scanning surface which is protected from contamination by alkali metals constituting the electron-emissive layer by means of insulation rings provided in the scanning section. One of the insulation rings also set the critical spacing between the target and a mesh electrode.

[56] **References Cited**

11 Claims, 6 Drawing Figures

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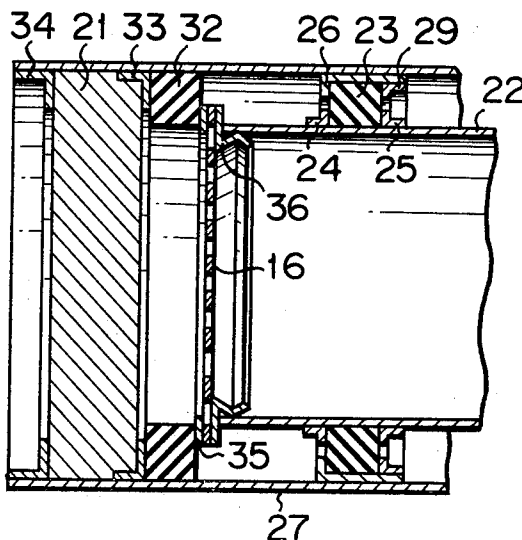


FIG. 1

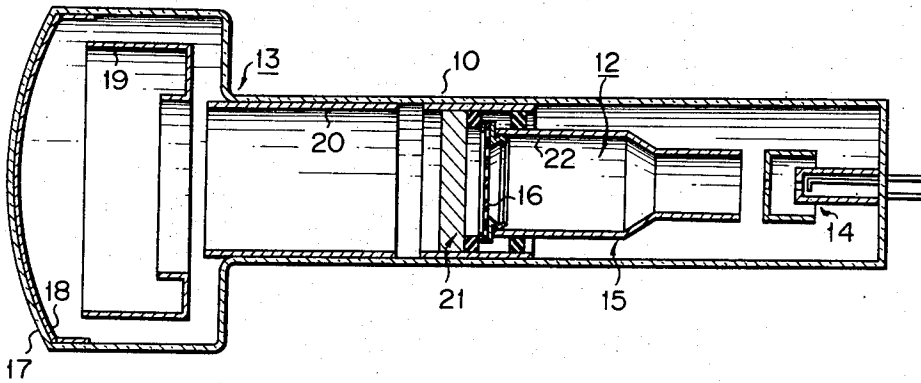


FIG. 2

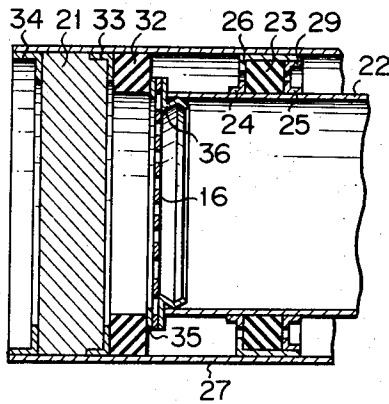


FIG. 4

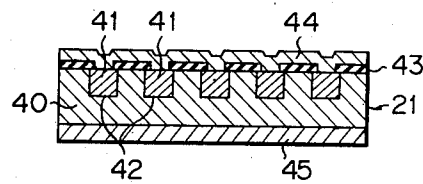


FIG. 5

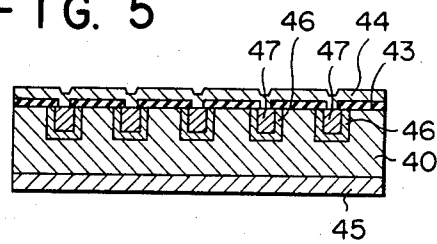


FIG. 6

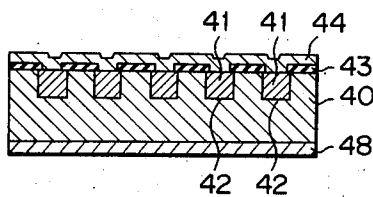


FIG. 3

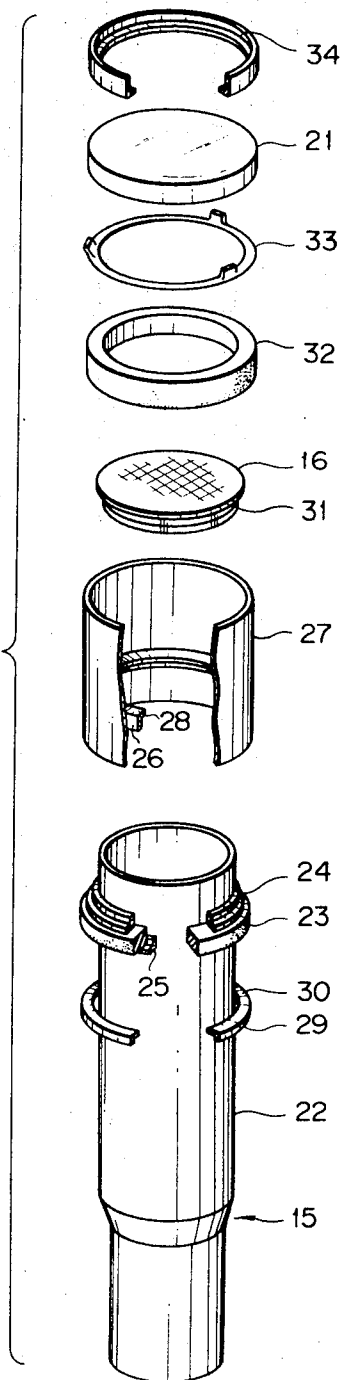


IMAGE PICKUP TUBE SEMICONDUCTOR TARGET SUPPORT STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATION

This is a Continuation-in-part application of our copending application, Ser. No. 889,756, filed on Dec. 31, 1969, now abandoned.

BACKGROUND OF THE INVENTION:

This invention relates to an image pickup device or tube having an electron-emissive surface.

Known devices for converting foreground objects located in the dark and invisible to the naked eye to a bright optical image so as to be reproduced on a television Braun tube include special tubes such as secondary electron conductivity vidicon (SEC vidicon) and intensifier vidicon. These image pickup tubes generally have such an arrangement as a combination of a known image intensifier and vidicon. Namely, these tubes generally comprise a section wherein there is provided an electron-emissive surface, light entering it being converted to photoelectrons which are further accelerated, and another section wherein there is provided an electron multiplication target and said accelerated photoelectrons entering said target being taken out in the form of electrical signals by electron beam scanning.

Such an electron multiplication target is generally made of ion conducting glass or electron conducting glass.

An image pickup tube using a target formed of the aforementioned material could not be expected to fully effect the electron multiplication thereby resulting in the lack of sensitivity. Furthermore, said target is apt to be damaged in use.

The object of this invention is to provide an image pickup tube comprising an image intensifier section, scanning section and a semiconductor target, which is capable of effecting high sensitivity and has the target least liable to be damaged in high contrast.

SUMMARY OF THE INVENTION

An image pickup tube according to the invention comprising an image intensifier section and scanning section has a semiconductor target provided with an accelerating layer for accelerating carriers produced by impingement of electrons. An image pickup tube using a semiconductor target which is not provided with such an accelerating layer can not display full sensitivity and high contrast, because the electrons entering said target have extremely small energy. Further, mere substitution of the aforesaid semiconductor target with an accelerating layer for the conventional glass target can not realize the desired effect. The reason is that when the electron-emissive surface of an image intensifier section or image section is activated by alkali metals as is generally practised, said alkali metals are likely to be introduced into the scanning section and be deposited on the scanning surface of the target to deteriorate its characteristics. With the image pickup tube of this invention, therefore, there are disposed a pair of insulation members near the target so as to prevent the materials constituting the electron-emissive surface from being deposited on the scanning surface of the target. One of the insulation members also defines the

critical spacing between the target and a mesh electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional view of an intensifier vidicon according to an embodiment of the present invention;

FIG. 2 represents, partly in section, a part of the vidicon of FIG. 1, that is, an electron multiplication target and its support member;

FIG. 3 shows perspective views, with part broken away, of the dismembered elements constituting a part of the vidicon of FIG. 1;

FIG. 4 is a sectional view of a form of electron multiplication target used in the vidicon of FIG. 3;

FIG. 5 is a sectional view of another form of said target; and

FIG. 6 is a sectional view of still another form of said target wherein there is formed a metal layer on one side of the substrate.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

There will now be described by reference to the drawings an electron multiplication target according to an embodiment of the present invention and an intensifier vidicon including said target.

Referring to FIG. 1, numeral 10 represents an evacuated envelope, which is divided into a scanning section 12 and an image section or image intensifier section 13 with the later described semiconductor electron multiplication target interposed therebetween. Said scanning section 12 comprises an electron gun assembly 14 disposed at one end of the envelope 10, a long cylindrical grid electrode 15 located ahead of said assembly 14 and a field mesh electrode 16 stretched across the front opening of said electrode 15. Said image section 13 comprises an electron-emissive surface 18 formed on the inner wall surface of the front or face plate 17 of said envelope 10, first and second cylindrical electrodes 19 and 20 for focusing and accelerating electrons emitted from said electron-emissive film 18 or primary electrons and said electron multiplication target 21 disposed behind these two electrodes 19 and 20 which will be further described later. This electron multiplication target is so positioned as to optically shut off said scanning section 12 and image section 13 from each other.

There will now be described concrete shielding means by reference to FIGS. 2 and 3. On the outer periphery near the opening of the large diameter section 22 of said grid electrode 15 is coaxially fixed an annular insulation member 23 by cylindrical metal stoppers 24 and 25 having an L-shaped cross section which are disposed on both sides of said insulation member 23 respectively, and fixed to said large diameter section 22, for example, by spot welding. On the large diameter section 22 of said grid electrode 15 is mounted a cylindrical target support 27 constituting a target electrode. Said support 27 has an inner diameter to match the outer diameter of the aforesaid insulation member 23 and includes an annular metal stopper 26 having an L-shaped cross section and coaxially fitted to the inner wall of the support 27. This support 27 and the aforesaid large diameter section 22 of the grid elec-

trode 15 are fixed to each other by clamping the end portion of said annular insulation member 23 between the protruding wall 28 of said metal stopper 26 and the bent wall 30 of a new annular metal stopper 29 having an L-shaped cross section. The mesh electrode 16 comprises a small diameter portion 31 acting as a spring and is fixed to the grid electrode 15 with said small diameter portion 31 inserted into the open end part of the large diameter section 22 of said grid electrode. Further inside of said cylindrical target support 27 are coaxially arranged in turn a cylindrical insulation member 32 whose outer diameter fits the inner diameter of the target support 27 and whose inner diameter is smaller than the outer diameter of said mesh electrode 16, an annular spring electrode 33 and said target 21. To the foremost end of the target support 27 is welded an annular metal stopper 34 having an L-shaped cross section. The interval between the field mesh electrode 16 and target 21 is defined by the length of said cylindrical insulation member 32. The cylindrical insulation members 23 and 32 may be made of, for example, ceramic. Said target 21 and its cylindrical target support 27 are electrically connected by the projections formed on said spring electrode 33. The mesh electrode 16 is interposed, as shown in FIG. 2, between a washer 35 fitted to said cylindrical insulation member 32 and a spring electrode 36. Said mesh electrode 16 is further electrically connected to said grid electrode 15 through said spring electrode 36.

The shielding means of the aforementioned construction is capable of not only optically shielding the image and scanning sections from each other by two insulation members 23 and 32, but also protecting the scanning surface of the semiconductor target from contamination. With the intensifier vidicon, an electron-emissive layer has heretofore been formed by thermally evaporating electron-emissive materials and alkali metals on the inner surface of the front part of the intensifier section. In this case, it was impossible to prevent the deposition of said alkali metals on the scanning section of the target.

According to the image pickup device of this invention, however, there are disposed near the end of a long cylindrical electrode a cylindrical supporting member 27 and two insulation members 23 and 32 at prescribed intervals, thereby substantially preventing said alkali metals from being deposited on the scanning surface of the target. One insulation member 23 is intended to prevent the alkali metals from intruding into the scanning section through the interstice between the cylindrical member 27 and envelope 10. The other insulation member 32 is used to prevent said alkali metals from being conducted into the scanning section through the interstice between the target 21 and cylindrical member 27. The latter insulation member 32 concurrently plays, as described above, the role of defining the distance between the target and mesh electrode.

There will now be described the aforementioned electron multiplication target 21 by reference to FIG. 4. This target is formed of an N-type conductivity silicon substrate 40 having, for example, a specific resistance of $10\Omega\text{-cm}$. On one side of said substrate 40 are formed a plurality of P-type conductivity small regions 41 at a prescribed space by selective diffusion of

boron so as to define PN junctions 42 between said N-type substrate 40 and P-type regions 41. One side of said substrate except the P-type regions is coated with a protective film 43 of insulation material, for example, silicon dioxide. Further on the same side of said substrate 40 is mounted a film of antimony selenide 44 about 500 Å thick in a manner to cover said protective film 43 and P-type regions 41 in order to prevent said protective film 43 from being unnecessarily charged. Obviously, said antimony selenide film 44 should have a sufficiently high resistance to prevent the resolution of said target 21 from being obstructed. On the other side of said substrate 40, namely, that side thereof into which there are introduced image photoelectrons, there is formed by diffusion an impurity layer 0.5 microns deep consisting of a high concentration of phosphorus, namely an N⁺-type conductivity layer 45, thus resulting in a potential gradient between said substrate 40 and N⁺-type conductivity layer 45.

A target according to the present invention is not limited to the type having the aforesaid diode construction, but may be of, for example, transistor construction. FIG. 5 represents a concrete example of the latter construction. The same parts of the figure as those of the aforesaid embodiment are denoted by the same numerals and description thereof is omitted. On one side of an N-type conductivity silicon substrate 40 is formed an N⁺-type conductivity layer 45 and on the other side an insulation film 43 and a semi-insulating film 44, for example made of antimony selenide or antimony sulfide, as shown, in the same manner as used in the preceding embodiment. On that side of the substrate on which there is deposited said insulation film 43 there are formed by selective diffusion a plurality of P-type conductivity mosaic regions 46 at a prescribed space. In each of said P-type conductivity regions is formed an N-type conductivity region 47. As a result, said P-type and N-type conductivity regions 46 and 47 and substrate jointly form N-P-N construction.

With the aforementioned device, there is defined a potential gradient between said N-type conductivity substrate and the N⁺-type conductivity layer formed on that side of said substrate into which there are introduced image photoelectrons. Said potential gradient allows minority carriers generated by introduction of said image photoelectrons into the substrate to proceed to the PN junctions at an accelerated speed, thus preventing the possibility of said minority carriers being extinguished while travelling to said PN junctions, thereby effectively amplifying said image photoelectrons to a far greater degree than is possible with any prior art device.

According to the present invention there is formed in a semiconductor substrate a region capable of accelerating minority carriers. Said region may be prepared not only by the aforesaid diffusion method, but also, for example, in the following manner, as concretely illustrated in FIG. 6. The same parts of FIG. 6 as those of the aforementioned embodiments are denoted by the same numerals and description thereof is omitted. On one side of an N-type conductivity silicon substrate 40 are formed a plurality of P-type conductivity regions 41 2 microns deep at a prescribed space so as to define PN junction 42 with said substrate 40. On the first mentioned side of said substrate 40 is

formed an insulation film, for example, of silicon dioxide or silicon nitride in a manner to cover the exposed part of each PN junction 42. On the remaining exposed parts of said side of the substrate, namely, on the surface of each P-type conductivity region 41 and also on said insulation film 43 there is deposited a film of antimony sulfide 44 about 500 Å thick. On the other side of said substrate 40, namely, that side thereof into which there are introduced image photoelectrons, there is deposited a metal layer 48 having a thickness of several hundred Å units, namely, a thickness sufficiently small to allow electrons to penetrate therethrough which are accelerated with several kilovolts or ten and odd kilovolts. Since said metal layer 48 consists of a material displaying a smaller work function than the silicon constituting said substrate, for example, aluminum or antimony, there prevails a potential gradient between said metal layer 48 and substrate 40, obtaining the same effect as in the aforesaid embodiments. It will be apparent that where said substrate 40 is of P-type conductivity, then use of a substance exhibiting a larger work function than the material of said substrate, for example, tellurium, indium or platinum, will generate the same potential gradient as described above.

The target according to the last mentioned embodiment not only has the same effect as that of the preceding ones, namely, the effect of prominently amplifying image photoelectrons, but also can be expected to offer the following advantages.

The metal layer deposited on that side of the substrate into which there are introduced image photoelectrons allows said electrons to proceed to the substrate without exerting any harmful effect thereon, whereas said metal layer serves the purpose of shielding any extra light. As a result, minority carriers are only generated in the substrate by image-forming electrons, enabling the image pickup tube of the present invention to perform excellent resolution.

However, the prior art device has the drawbacks that where there is formed a face plate or photoelectric plate in the image section of the pickup tube by the deposition of an electron-emissive material, and the activation of alkali metals for example, cesium, that side of the target on which there are introduced image electrons is eventually contaminated by the cesium, thereby decreasing properties of said target. For example, where the device is of a diode construction, there will fall the yield voltage, or increase the dark current. In contradistinction to this, the target according to the last mentioned embodiment wherein the metal layer acts as a protective film is saved from the aforesaid deterioration of properties.

In all the above-mentioned embodiments the target substrate consisted of silicon, but the target may be prepared from other semiconductor materials, for example, germanium or gallium arsenide. Further, the substrate may be of P-type conductivity instead of N-type conductivity as used in the foregoing embodiments. In this case, however, the aforementioned island regions should, of course, be of N-type conductivity.

What we claim is:

1. An image pickup tube comprising an evacuated envelope, an electron gun disposed at one end of said envelope, a cylindrical electrode for accelerating elec-

tron beams from said electron gun, a cylindrical supporting member within said envelope having a diameter larger than the accelerating electrode, the supporting member and the accelerating electrode being fitted into each other at mutually facing end portions and coaxially disposed in the envelope, a field mesh electrode positioned in the supporting member to close the open end of the cylindrical accelerating electrode, a semiconductor target positioned in the supporting member spaced from and facing the mesh electrode, a pair of annular insulation members, one of which is interposed between the cylindrical supporting member and the accelerating electrode and the other of which is sandwiched between the peripheral portions of said target and said mesh electrode to define a predetermined spacing therebetween, an electrode to define a predetermined spacing therebetween, an electron-emissive surface provided on the other end of said envelope to convert the light of an image to electrons and electrode means provided between the electron-emissive surface and the target to accelerate said electrons and focus them on the target, the semiconductor target comprising a semiconductor substrate having a plurality of PN junctions formed on the scanning side of said substrate facing said electron gun and an accelerating layer formed on the image electron incident side of said substrate.

2. The image pickup tube according to claim 1 wherein said accelerating layer has the same type of conductivity as, but contains a higher concentration of impurities than, said substrate.

3. The image pickup tube according to claim 2 wherein said substrate and accelerating layer are of N-type conductivity.

4. The image pickup tube according to claim 1 wherein said target includes a metal film on the image electron incident side of the substrate to form said accelerating layer between the substrate and metal layer.

5. The image pickup tube according to claim 1 wherein said target includes a plurality of first separate regions on one side of said substrate having one type of conductivity whose conductivity is of opposite type to said substrate, thereby defining PN junctions between said substrate and regions.

6. The image pickup tube according to claim 5 wherein said target includes a plurality of second separate regions respectively formed in said first regions, the second regions having opposite type of conductivity from the first regions thereby defining PN junction between the first and second regions.

7. The image pickup tube according to claim 5 wherein said target includes an insulating layer on the image electron incident side of the substrate except on said first separate regions.

8. The image pickup tube according to claim 7 wherein said target includes a semi-insulating film on the insulating layer and first separate regions.

9. The image pickup tube according to claim 1 wherein said insulation members are made of ceramic.

10. The image pickup tube according to claim 1 wherein said insulation members are spaced from each other along the axis of said cylindrical supporting member, said other insulation member preventing alkali metals from being conducted into the scanning section through the interstice between the cylindrical supporting member and the target.

11. The image pickup tube according to claim 1 wherein the cylindrical support member and the accelerating electrode have annular stopper members extending therefrom, said one insulation member being interposed between said stopper members.

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