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[54] **PHOTOCONDUCTIVE TARGET OF AN IMAGE TUBE**

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[52] **U.S. Cl.** .. **317/235 R**, 317/235 N, 317/235 NA, 317/235 AC, 317/241

[51] **Int. Cl.** **H01l 15/00**; 250/213

[58] **Field of Search** .... 317/235 N, 235 AC, 241, 317/234 S, 235 NA; 313/66

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[57] **ABSTRACT**

A target for an image pickup tube comprising a light-transmitting conductive layer supported on a light-transmitting substrate and a photoconductive layer with rectifying contact at least at one of its sides; in which the photoconductive layer has a portion 1,000 A or thicker which comprises a multiplicity of thin films of two or more different materials with different photoconductive characteristics, each having a thickness of not more than 100 A, the thin films of the different materials being laid alternately one on another.

6 Claims, 6 Drawing Figures

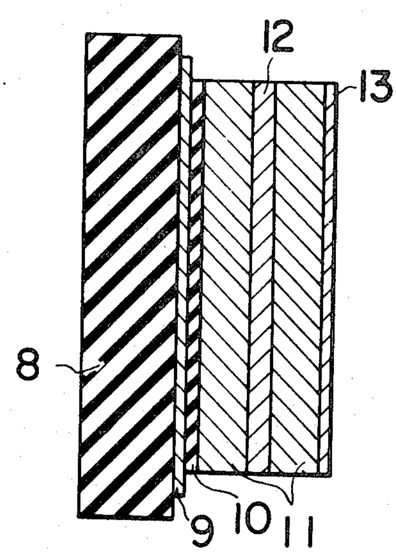

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FIG. 1

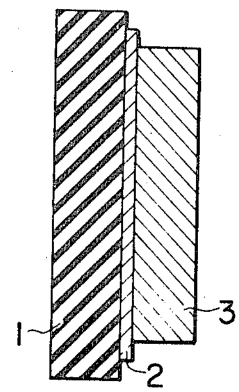


FIG. 4

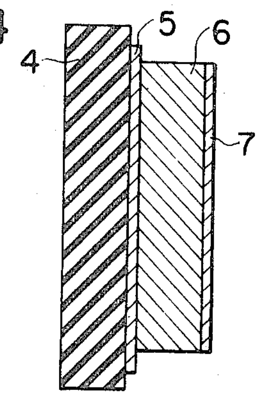


FIG. 2 PRIOR ART

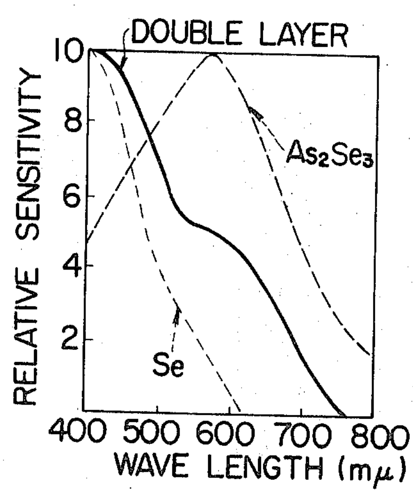


FIG. 3

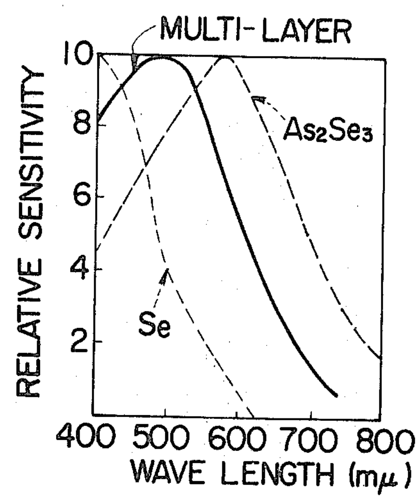


FIG. 5

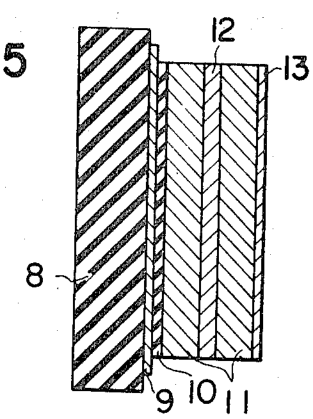
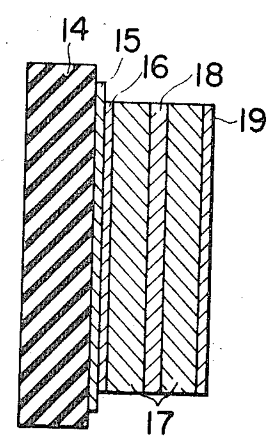


FIG. 6



PHOTOCONDUCTIVE TARGET OF AN IMAGE TUBE

The present invention relates to a target of an image pickup tube or more in particular to a target of an image pickup tube of vidicon type utilizing the rectifying contact of a photoconductive semiconductor.

The materials of the target for the image pickup tube now in commercial use include photoconductive semiconductors such as Sb_2S_3, PbO and Si. A target of Sb_2S_3 is characterized by an ohmic contact, while those made of PbO or Si generally have a rectifying contact or is of a PN junction type. The target with the rectifying contact or PN junction has many advantages including the fact that they allow less dark current, is higher in sensitivity and greater in response speed than the target with an ohmic contact. The manufacture of an image pickup tube with a PN junction of single crystal such as a vidicon with Si target requires highly complex processes, and also it is very difficult to remove an imperfection of a picture attributable to the defects of a crystal bulk or unsatisfactory processes. A target of a thin film with a rectifying contact, by comparison, is manufactured by comparatively simple processes, but it is not an easy matter to achieve a rectifying contact which is used successfully for a vidicon target, the known materials suitable for such a purpose being limited to PbO and few others including selenium and its compounds.

Further, in the conventional co-evaporation method of forming an evaporated thin film of a compound semiconductor with a desirable sensitive spectral region by controlling its composition, a plurality of different component elements are deposited simultaneously from a plurality of sources of evaporation. In such a method, however, the plurality of sources are located at different positions relative to the substrate and therefore the composition of the resulting layer on the substrate is not necessarily uniform at every point on the substrate.

For the above mentioned reasons, it is difficult in the conventional methods to obtain a thin film with a rectifying contact by evaporation which fully meet, all the requirements of an image pickup tube including a superior dark current characteristic, spectral sensitivity characteristic and after image.

The inventors have discovered that the alternate deposition of a multiplicity of thin films of different substances one on another makes it possible to obtain a photoconductive layer with a photoconductive characteristic quite similar to that of a material resulting from the uniform mixing of such substances. Generally, when a plurality of thin films with different photoconductive characteristics are laid one on another, the resulting characteristic is the sum of the different photoconductive characteristics involved. If, however, the thickness of each component thin film is sufficiently small and the laminated structure consists of a multiplicity of such thin films deposited alternately one on another, the resulting photoconductive characteristic is intermediate with respect to those of the component thin films.

Accordingly, it is an object of the present invention to obviate the disadvantages of the conventional target of an image pickup tube and to provide a novel target of an image pickup tube which is capable of controlling the spectral sensitivity characteristic of the image

pickup tube considerably without adversely affecting its characteristics of dark current and after image.

In order to achieve the above mentioned object, the target of the image pickup tube according to the present invention comprises a light-transmitting substrate, a light-transmitting conductive layer and a photoconductive layer deposited on the light-transmitting conductive layer and including a part 1,000 A or thicker consisting of at least two thin films of different photo-conductive characteristics alternately laid one on another, each of the thin films being 100 A or thinner said photo-conductive layer having at least one rectifying contact on its surface.

The above and other objects, features and advantages will be made apparent by the detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram showing a section of a target for the image pickup tube according to the present invention;

FIG. 2 is a diagram showing the spectral sensitivity of a conventional photo-conductive double layer consisting of Se and As_2S_3;

FIG. 3 is a diagram showing the spectral sensitivity of a layer consisting of Se and As_2S_3 used for the target for the image pickup tube according to the present invention; and

FIGS. 4 to 6 are diagrams showing sections of embodiments of the present invention.

EMBODIMENT 1

An embodiment of the invention is illustrated in FIG. 1, in which reference numeral 1 shows a glass substrate, numeral 2 a light-transmitting conductive layer, and numeral 3 a photo-conductive layer. The photoconductive layer 3 of about 3 microns thick is made by depositing by evaporation a multiplicity of selnium films each about 20 A and As_2Se_3 films each about 7 A alternately one on another in a vacuum of 5×10^{-6} Torr. A rectifying contact is formed between the light-transmitting conductive layer 2 and the photoconductive layer 3. A photo-conductive layer 3 consisting of only a selenium film has a superior rectifying contact but has the disadvantage of insufficient sensitivity to light of long wavelength. When the photo-conductive layer 3 is formed of only As_2Se_3, by contrast, a high sensitivity to red light is obtained but it is impossible to form a superior rectifying contact.

In case the photo-conductive layer 3 were made of comparatively thick Se and As_2Se_3 films of, say, 5,000 A each, two peaks of spectral sensitivity corresponding to those of the individual component films of Se and As_2Se_3 respectively would be observed as shown in FIG. 2. The photo-conductive layer 3 according to the present invention, by contrast, which comprises a multiplicity of comparatively thin Se and As_2Se_3 alternate films of, say, 50 A in thickness each having its peak of spectral sensitivity intermediate with respect to the two hypothetical peaks which otherwise might occur separately for the two component film elements. In the latter case, it is considered that the photo-conductive layer 3 has similar characteristics as if Se and As_2Se_3 are mixed uniformly. Such similarity is achieved only when the thickness of each film of Se and As_2Se_3 is approximately 100 A or less.

Further, it is possible by employing the construction of the photo-conductive layer according to this embodiment to achieve a photo-conductive layer superior in dark current characteristic, after image characteristic and sensitivity to long wavelength light as shown in Table 1 without adversely affecting the rectifying characteristic.

TABLE 1 — Characteristics of Target for Image Pickup Tube According to Embodiment 1

target construction	dark current at target voltage of 50 V	wavelength at peak spectral sensitivity	lag (after 3 fields)	after image
selenium only	1 nA	400 mμ	6%	long
As_2Se_3 only	20 nA	580 mμ	50%	very long
this invention	1 nA	520 mμ	6%	short

Furthermore, although in the above embodiment the different types of film may be employed, more than three different types of films may be deposited one on another to obtain the photo-conductive layer according to the invention by using as many evaporation sources. Also, it is possible to achieve any desired mixing ratio by varying the thickness of each film accordingly.

For the practical purpose of controlling the spectral sensitivity of the photo-conductive layer the above mentioned multi-layer construction is not necessarily required all over its total thickness. Most of the energy of light entering the photo-conductive layer is absorbed at its portion within the depth of several thousands of A from the surface thereof. Therefore, the portion of the layer as thick as 1,000 A or more from the surface has a controlling effect upon the spectral sensitivity of the photo-conductive layer.

If the photo-conductive layer with the above mentioned construction is to be used for a target of the image pickup tube, its dark current characteristic, after image characteristic, lag characteristic as well as the spectral sensitivity are required to be maintained at a satisfactory level for the image pickup tube. It is already mentioned that a desirable construction for the target of an image pickup tube is of the rectifying contact type. Since the characteristic of the target of the rectifying contact type largely depends upon the shape of the rectifying barrier, the portion of the photo-conductive multi-layer for controlling the spectral sensitivity must be so selected as not to adversely affect the other characteristics of the photo-conductive layer. To achieve maximum utilization of incident light, it is recommended that the multi-layer portion of the photo-conductive layer be located as near to the plane of incidence as possible so far as the effect of the rectifying barrier is not reduced.

The photo-conductive layer used as a target for an image pickup tube generally has the thickness of 2 to 20 microns, and it is possible, by providing a portion of the photo-conductive layer as thick as 1,000 A for controlling the spectral sensitivity of the photo-conductive layer, to limit the function of such portion to the controlling of the spectral sensitivity without any substantial effect upon the lag, after image and dark current characteristics of the photo-conductive layer.

EMBODIMENT 2

Referring to FIG. 4 showing another embodiment of the invention, reference numeral **4** denotes a glass substrate, numeral **5** a light-transmitting conductive layer,

and numeral **6** a photo-conductive layer approximately 2 microns thick consisting of a multiplicity of selenium films each about 5 A thick and CdSe films each about 20 A thick alternately deposited one on another. Reference numeral **7** shows a CdTe film with a thickness of approximately 1,000 A. In the embodiment under consideration, a rectifying contact is interposed between the photo-conductive layer **6** and the CdTe film **7.** A photo-conductive layer consisting of only selenium films develops no sufficient sensitivity to light of long wavelengths, while one with only CdSe films does not satisfy the requirements for rectifying contact. The employment of a multi-layer as represented by the photo-conductive layer **6** consisting of alternately deposited multiplicity of selenium and CdSe films makes it possible to obtain a target superior both in rectifying contact and in sensitivity to long wavelength as is apparent from Table 2.

TABLE 2 — Characteristics of Target for Image Pickup Tube According to Embodiment 2

target construction	dark current at target voltage of 50 V	wavelength at peak spectral sensitivity	lag (after 3 fields)	after image
selenium only	1 nA	400 mμ	6%	long
CdSe only	35 nA	650 mμ	30%	long
this invention	2 nA	600 mμ	15%	short

In this embodiment, CdTe may be replaced by ZnS, CdS, ZnSe, CdSe or a mixture of any ones of them which has a property similar to that of CdTe.

EMBODIMENT 3

A third embodiment of the invention is shown in FIG. **5.** In the figure, reference numeral **8** shows a glass substrate, numeral **9** a light-transmitting conductive layer, the numeral **10** a film of MnF_2 200 A thick. The interposition of the insulating material MnF_2 between the light-transmitting conductive layer **9** and the selenium film **11** permits the reverse breakdown voltage of the rectifying contact between the light-transmitting conductive layer **9** and the selenium film **11** to be increased. The purpose of increasing the reverse breakdown voltage of the rectifying contact is also achieved by the interposition of PbF_2, CaF_2, MgF_2, Al_2O_3, SiO, ZnS, As_2S_3, or the like insulating material instead of MnF_2. Incidentally, the thickness of the insulating film may be in the range from 10 to 1,000 A.

The selenium film **11** which is approximately 3 microns in thickness has a central portion **12** approximately 1,000 A thick including a multiplicity of selenium films each about 20 A and tellurium films each about 12 A alternately laid one on another. There is provided on the selenium film **11** an Sb_2S_3 film **13** about 10,000 A thick to improve the landing of the scanning electron beams. Although the Sb_2S_3 film **13** may be deposited by evaporation in a vacuum of 1×10^{-5} Torr. or thereabouts, a porous Sb_2S_3 film deposited by evaporation in an argon gas of about 5×10^{-2} Torr. is more effective for the purpose of effective landing of electron beams. However, since an Sb_2S_3 film which is porous through its whole thickness is too high in resistance, resulting in inferior characteristics, it is desirable that a porous film of Sb_2S_3 or As_2Se_3 be laid on a solid film of Sb_2S_3 deposited by vacuum evaporation to obtain an integrated Sb_2S_3 film. In the embodiment under consideration, the central portion **12** in the form of a multi-layer is such that an improved sensitivity to red light is obtained as shown in Table 3 without adversely affecting the rectifying contact formed of the light-transmitting conductive layer **9**, insulating film **10** and the selenium film **11**.

TABLE 3 — Characteristics of Target for Image Pickup Tube According to Embodiment 3

target construction	dark current at target voltage of 50 V	wavelength at peak spectral sensitivity	lag (after 3 fields)	after image
selenium only	1 nA	400 mμ	6%	long
Te only	large			
this invention	1 nA	600 mμ	7%	short

EMBODIMENT 4

A fourth embodiment of the invention is illustrated in FIG. **6**. Reference numeral **14** shows a glass substrate, numeral **15** a light-transmitting conductive layer, numeral **16** a ZnSe film approximately 500 A thick, and numeral **17** a photo-conductive layer about 3 microns thick which comprises a multiplicity of selenium films each about 40 A and arsenic films each about 5 A alternately laid one on another. The superior rectifying contact between the ZnSe film **16** and photo-conductive layer **17** is also achieved by using a ZnS or CdSe film of the same thickness in place of the ZnSe film. In this embodiment, too, an insulating film may be inserted on the side of the rectifying contact of the photo-conductive layer in order to improve the breakdown voltage of the rectifying contact in the reverse direction as in the preceding embodiment. The photo-conductive layer **17** is provided with a central multi-layer portion **18** about 2,000 A thick comprising a multiplicity of selenium films each about 40 A, arsenic films each about 5 A and tellurium films each about 30 A which are deposited alternately one on another.

An Sb_2S_3 film **19** about 1,000 A thick is provided on the photo-conductive layer **17** to improve the landing of the scanning electron beams. According to the present embodiment, the presence of the tellurium films in the layer **18** permits the sensitivity to red light to be improved as shown in Table 4 without adversely affecting the advantage of the rectifying contact.

TABLE 4—Characteristics of Target for Image Pickup Tube According to Embodiment 4

target construction	dark current at target voltage of 50 V	wavelength at peak spectral sensitivity	lag (after 3 fields)	after image
selenium only	1 nA	400 mμ	6%	long
arsenic only	large			
this invention	1 nA	580 mμ	8%	short

It will be understood from the above explanation that, in a target for an image pickup tube with a rectifying contact, the provision of a multi-layer consisting of a multiplicity of thin films of two or more different photo-conductive types alternately deposited one on another makes it possible to control more widely the spectral sensitivity of the target without adversely affecting the other characteristics thereof. For this reason, the present invention is applied with great advantages to the construction of a target for a color television image pickup tube or the like whose requrements for spectral sensitivity are very severe.

What we claim is:

1. A photo-conductive target for an image pickup tube comprising a light-transmitting substrate, a light-transmitting conductive layer deposited on said light-transmitting substrate and a photo-conductive layer deposited on said light-transmitting conductive layer, said photo-conductive layer containing selenium and including a portion not less than 1,000 A thick, said portion of said photo-conductive layer consisting of a multiplicity of thin films of at least two different materials with different photo-conductive characteristics, each having the thickness of 100 A or less, said thin films being laid alternately one on another.

2. A photo-conductive target for an image pickup tube according to claim **1**, further comprising one semiconductor layer selected from the group consisting of ZnS, CdS, ZnSe, CdSe, CdTe and a mixture thereof deposited on said photo-conductive layer, a rectifying contact being formed by said semiconductor layer and said photo-conductive layer.

3. A photo-conductive target for an image pickup tube according to claim **1**, in which said light-transmitting layer and said photo-conductive layer constitute a rectifying contact.

4. A photo-conductive target for an image pickup tube according to claim **2**, in which an insulating thin film with the thickness from 10 A to 1,000 A and comprising one selected from the group consisting of ZnS, PbF_2, MnF_2, CaF_2, MgF_2, Al_2O_3, SiO and As_2S_3 is provided adjacent to that side of said photo-conductive layer which has said rectifying contact.

5. A photo-conductive target for an image pickup tube according to claim **3**, in which an insulating thin film with the thickness from 10 A to 1,000 A and comprising one selected from the group consisting of ZnS, PbF_2, MnF_2, CaF_2, MgF_2, Al_2O_3, SiO and As_2S_3 is provided adjacent to that side of said photo-conductive layer which has said rectifying contact.

6. A photo-conductive target for an image pickup tube according to claim **1**, in which the surface of said photo-conductive layer to be scanned by an electron beam is covered with one selected from the group consisting of a vacuum-evaporated Sb_2S_3 film, a porous Sb_2S_3 film, a combination of a vacuum-evaporated Sb_2S_3 and a porous Sb_2S_3 film, and a porous As_2Se_3 film deposited on a vacuum-evaporated Sb_2S_3 film.

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