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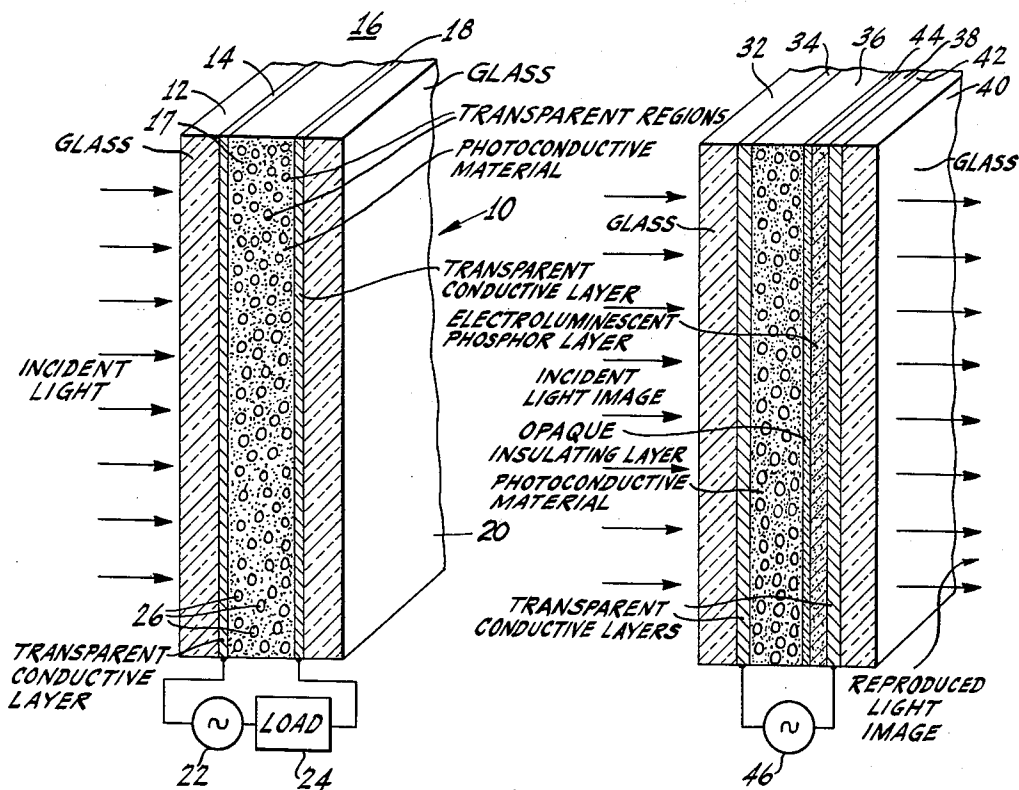
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RADIANT ENERGY SENSITIVE DEVICE

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Fig. 1.

Fig. 2.



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RADIANT ENERGY SENSITIVE DEVICE

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9 Claims. (Cl. 250-213)

This invention relates to radiant energy sensitive devices utilizing radiant energy sensitive surfaces or layers.

This application is a continuation of applicant's co-pending application, Serial Number 478,675, filed December 30, 1954, now abandoned.

This invention is directed to improving the sensitivity of such devices. One example is a certain type of picture reproducer which, for design reasons, utilizes a thick layer of photoconductive material as a light sensitive element. In such devices the photoconductive layer may be so thick that light is unable to penetrate completely through the layer. Hence, under excitation, there exists through the thickness of the photoconductive layer a low impedance layer where the light penetrates and a series high impedance layer which the light does not penetrate and which remains unsensitized. The presence of such an unsensitized layer causes inefficient operation of the device and greatly detracts from the overall performance of the device, especially its sensitivity, and, if the device is a picture reproducer, its brightness and amplification.

The probable uses of this invention include area photo devices, whether the device is a photocell itself or is used as a layer scanned with an electron beam or light beam to give signals. It would also apply to photolayers used in conjunction with electroluminescent layers or other light producing layers for picture reproduction or amplification.

One type of picture reproducing device to which this invention applies utilizes a projection screen constituted of a layer of photoconductive material and a layer of electroluminescent material sandwiched between two transparent electrodes. The electroluminescent material is constituted of particles of luminescent phosphor material embedded in a dielectric and having the property of emitting light under the influence of an electric field. A voltage is applied across the two electrodes to provide an electrical circuit in which the impedances of the two layers are in series. It has been necessary to make the thickness of the photoconductive layer much greater than that of the electroluminescent layer so that the impedance of the photoconductive layer in the dark will be many times that of the electroluminescent layer, and a greater fraction of the applied voltage will be developed across the photoconductive layer. Under these conditions, the voltage across the electroluminescent layer is below the threshold voltage required to cause visible luminescence and no light is emitted from the electroluminescent layer. When light falls on the photoconductive material, its impedance is lowered in the areas where the light strikes, and a greater fraction of voltage is applied across the electroluminescent material directly in contact with the illuminated areas of the photoconductor. The electroluminescent material is thus caused to emit light.

The light emission increases with an increase in the voltage applied across the electroluminescent layer so that a half-tone image can be projected on the photoconductive material and a corresponding half-tone image will be reproduced on the electroluminescent material. In addition, if the input image is of low intensity, the output image can be an amplified light image. Also an invisible image, such as an infrared image or an ultraviolet image can be converted or reproduced in visible form

if a photoconductive layer responsive to infrared or ultraviolet radiation is used.

In some devices, the electroluminescent layer is about 1 mil in thickness, and to achieve the required voltage distribution between the two layers in the dark, the photoconductive layer is made about 10 mils thick. Such a thick photoconductive layer is not very efficient because the major portion of the light is absorbed within a short depth of the photoconductor and the lower depths remain relatively unilluminated. The problem, therefore, is to devise some means whereby the effective depth of the photoconductor excited by the incident light is greatly increased, in order to provide a more efficient photoconductive layer and thus produce greater light output from the electroluminescent layer. It has been proposed to make a photoconductive layer more transparent by making a layer of photoconductive material formed in separate photoconductive regions which are separated laterally by transparent regions. But this proposed structure has a disadvantage in that the overall effective photoconductive area which is responsive to light is substantially less than the total area of the photoconductive layer.

It is therefore an object of this invention to provide a radiant energy sensitive device having improved sensitivity.

It is a further object to provide an improved light sensitive device having a continuous photoconductive layer having substantial thickness but which nevertheless permits light to penetrate through a greater effective depth.

It is a further object to provide an improved light image reproducer of the kind including as one of its elements a continuous photoconductive layer of improved transparency.

The foregoing and other objects may be achieved in accordance with one embodiment of the invention by providing a light sensitive device with a continuous photoconductive layer of substantially uniform thickness substantially greater than a predetermined light penetrating thickness but having portions which are more transparent to incident light than the remaining portions of said layer. The transparent portions are uniformly distributed throughout the entire volume of the layer so that the light may be permitted to more easily penetrate the layer and reach the lower depths. The transparent portions may be tiny transparent particles of matter such as glass beads interspersed with and completely surrounded by the particles of the photoconductive material with or without the use of a binder which may be of transparent plastic material.

While the devices described herein have particular utility in detecting or reproducing light or light images falling in the visible spectrum, the principles of this invention apply also to other types of radiation, for example X-rays, infrared radiations, ultraviolet light radiation and the like. Here, for simplicity, the term "radiant energy" will be understood to encompass X-rays as well as visible and invisible light, and the term "photoconductive" will be employed as a generic expression for the property of responding to radiant energy.

In the single sheet of drawings;

FIG. 1 is a perspective view partially in section of a light sensitive cell constructed in accordance with the invention; and

FIG. 2 is a similar view of an image reproducer constructed according to the invention.

In the figures of the drawing, the relative thicknesses of the separate layers are greatly exaggerated in order to show each layer clearly.

In accordance with the present invention, as illustrated in FIG. 1, a photosensitive cell 10 comprises a first transparent support plate 12, which may be glass or plastic, a thin transparent conductive film 14 thereon, which may

be a film of tin chloride, a continuous photoconductive layer 16 of substantially uniform thickness, a conductive film 18, which may also be transparent like the film 14, and a second support plate 20, which may also be transparent. The film electrodes 14 and 18 are connected in series with a voltage source 22 and a load 24. Conductive film 18 and support 20 could also be replaced by a conductive base of sheet metal.

The continuous photoconductive layer 16 comprises photoconductive material 17 combined with particles 26 which are more transparent to light than the material 17. The particles 26 may be tiny beads of glass or plastic, or generally any transparent solid material. The particles 26 are preferably uniformly distributed throughout the volume of the layer 16. Therefore, when the cell 10 is subjected to light, the light will pass into and through the light transparent particles 26 and illuminate the entire depth of the photoconductive layer 16.

Provision of these light transparent particles avoids the limitations of reduced sensitivity of conventional photoconductive layers formed without the particles. Conventional layers of a thickness greater than a given light penetration thickness have the serious limitation in that the lower regions of the layer are not reached by the light. The impedance remains high in these lower regions and the sensitivity of the cell is considerably reduced. By means of this invention, then, the overall thickness of the layer 16 may be many times the minimum thickness of a conventional layer without the transparent portions in which substantially all light is absorbed, and yet the light will reach and excite the lower depths of the layer.

The transparent particles 26 may be provided by mixing tiny glass beads or plastic bits with the photoconductor, which may for example be cadmium sulfide powder or crystals. The photoconductive material 17 may be photoconductive powder in dry form or mixed with a plastic binder. The plastic binder serves as a cohering agent by which the substances of the mixture are bound together.

In the above device the objective is to provide a sufficient number of transparent portions to reduce the overall thickness of the photoconductive layer to an effective thickness which is comparable to the light penetration thickness without reducing the effective area of the layer responsive to input radiation. Further, the number of these portions should be such that the entire area of the photoconductor will be illuminated by the penetrating light. For use in image reproducing devices, the size of these portions should be smaller than an image element.

A photoconductive layer formed with light transparent particles in a manner above described may be used to improve the light gain of a certain type of electroluminescent picture reproducer. Referring to FIG. 2, the picture reproducing device comprises a transparent support plate 32, made of glass, for example, a transparent conductive film 34 on a surface thereof, a continuous photoconductive layer 36 on the film 34, a layer 38 of electroluminescent phosphor having one surface adjacent to the photoconductive layer 36 and having its other surface supported on a second transparent plate 40 provided with a transparent conductive film 42 in contact with the phosphor layer 38. If desired, a light opaque insulating layer 44 may be interposed between the photoconductive layer 36 and the electroluminescent layer 38. The conductive films 34 and 42 serve as electrodes for connecting the device to a voltage source 46, preferably alternating current.

The photoconductive layer 36 may comprise cadmium sulfide powder mixed with a suitable plastic binder, such as ethyl cellulose, methyl methacrylate, or polystyrene. In accordance with the present invention, the photoconductive layer 36 is rendered light transparent by the uniform admixture of many tiny transparent particles, for example, glass beads, in the manner hereinbefore described.

These particles should be appreciably smaller than any picture element so that picture resolution device will not be reduced on this account. The phosphor layer 38 may comprise particles of zinc sulfide phosphor activated with copper and mixed with a suitable dielectric material, such as ethyl cellulose for example.

To operate the device of FIG. 2 as a light amplifier or picture reproducer, consider the relative thickness of the photoconductive layer 36 and the phosphor layer 38 to be such that the series impedance of the photoconductive layer in the dark or unexcited condition is of the order of ten times that of the phosphor layer. Since these impedances are in series with the supply voltage 46, the apportioned voltage appearing across the photoconductive layer will be ten times the voltage appearing across the phosphor layer. Also consider the supply voltage to be adjusted so that the magnitude of the voltage appearing across the phosphor layer is just below the threshold value required to cause the phosphor to luminesce. Under these conditions then, with no incoming radiation incident on the photoconductor, no light is emitted from the phosphor.

An amount of light falling on an elemental area of the plate 32 will penetrate, with very little loss, the transparent plate 32 and the transparent film 34 and strike an elemental area of the photoconductive layer 36. The light will also penetrate with very little loss the transparent portions of the photoconductive layer where it strikes and will be absorbed in part by the photoconductive material upon which it impinges and which it penetrates. The end effect is that the light illuminates the whole depth of the layer 36 in the area where it strikes. The conductivity of the photoconductor throughout its entire thickness will increase in this area, conducting paths being established between the conductive film electrode and the phosphor layer 38 through the illuminated depth of the photoconductor. This increase in conductivity, or drop in impedance of the photoconductor, which is a function of the intensity of the incident light, causes a corresponding increase in the voltage appearing across the phosphor in an area directly adjacent to the excited photoconductor. The phosphor is thus caused to emit light in this area due to an increase at this localized area in the voltage above the threshold value required for luminescence. Because the intensity of the light emitted from the phosphor increases with increasing field developed across the phosphor, it is readily seen that an image with half tones can be reproduced on the phosphor surface which is a replica of the image incident on the photoconductor.

The opaque layer 44 may be a thin layer of black lacquer or it may be carbon black particles mixed with insulating material. The opaque layer 44, if used, will prevent light feedback from the phosphor layer to the photoconductive layer. The opaque layer 44 may be omitted, and light feedback will be prevented if the light emitted from the phosphor layer falls within a range of wavelengths lying outside that portion of the spectrum to which the photoconductive layer is sensitive. It may be advantageous, under certain circumstances, to omit the opaque layer and allow light feedback to enhance the amplification or to store a reproduced image even after the incident image is removed.

As indicated previously, if a uniformly thick solid layer of photoconductor is used in a picture reproducer of this kind, the incident light will not reach the lower depths of the photoconductive layer. Hence, the photoconductor will be inefficient in transferring the maximum desired proportion of the total supply voltage to the phosphor layer for any given level of incident light. With a device constructed according to FIG. 2, however, in which the photoconductive layer is provided with light transmitting portions which are distributed throughout the entire layer, this handicap is overcome. These light transmitting portions allow light to excite the photoconductor throughout its whole depth.

Any other material whose impedance is variable in response to radiant energy excitation may be used in place of the photoconductor described above. For example, cadmium selenide or lead sulfide may be used in all the devices described.

Thus the invention makes possible the use of radiant energy sensitive devices having much thicker radiant energy sensitive layers than conventional devices, to get high dark impedance.

What is claimed is:

1. A radiant energy sensitive device comprising a mixture of photoconductive material and a multiplicity of minute particles of a material which is more transparent to radiant energy than said photoconductive material, said mixture of materials being arranged in a sheet-like element, said mixture extending continuously over said sheet-like element.

2. A radiant energy sensitive device comprising a sheet-like element formed of a uniform mixture of photoconductive powder and a multiplicity of bead-like particles of a material which is more transparent to light than said photoconductive powder, said mixture extending continuously over said sheet-like element.

3. A light sensitive device comprising a composite layer of cadmium sulfide powder mixed with a plastic binder and a multiplicity of glass beads interspersed with said powder and binder, and two electrodes in contact with opposite sides of said layer, said powder and binder mixture extending continuously over said layer.

4. A radiant energy sensitive device comprising a sandwich structure including two continuous layers which are electrically in series over all areas thereof, one of said layers being formed of a uniform mixture of photoconductive material and a multiplicity of glass beads of a dimension smaller than an image element, the other one of said layers comprising electroluminescent phosphor material, and a pair of electrodes between which said two layers are disposed.

5. A radiant energy sensitive device comprising a sandwich structure including two continuous layers which are electrically in series over all areas thereof; one of said layers being formed of a uniform mixture of photoconductive powder particles in a plastic binder and particles of a material which is more light transparent than said photoconductive particles; the other of said layers comprising electroluminescent phosphor material; and a pair of electrodes between which said two layers are disposed.

6. A radiant energy sensitive device comprising a sheet-like support provided with a conductive surface, a continuous layer of predetermined thickness on said surface and formed of a uniform mixture of photoconductive material and particles of material which is more transparent to light than said photoconductive material, said particles having a dimension in the direction of the thickness of said layer which is small compared to said thickness, a layer of electroluminescent material in series over all areas with said first-mentioned layer, and a light transparent sheet-like electrode on said electroluminescent layer.

7. A radiant energy sensitive device comprising a sandwich structure including two continuous layers which are electrically in series over all areas thereof, one of said layers being formed of a uniform mixture of photoconductive material and a multiplicity of particles of material which is more light transparent than said photoconductive material, the other one of said layers comprising electroluminescent phosphor material, said first material layer having an overall thickness which is substantially greater than the size of said particles as well as the thickness of said electroluminescent layer, and a pair of electrodes between which said two layers are disposed.

8. A picture reproducer comprising a composite photoconductive layer of cadmium sulfide powder, a plastic binder for said powder and a multiplicity of glass beads uniformly interspersed with said powder and binder, a layer of electroluminescent material on said photoconductive layer, said photoconductive layer having a substantially greater impedance than said electroluminescent layer and a correspondingly greater thickness, and electrode means on said respective layers adapted to be connected to a source of voltage for applying an electric field on said layers, said powder and said binder extending continuously over said photoconductive layer.

9. In a radiant energy sensitive device a photoconductive layer, said photoconductive layer comprising photoconductive material interspersed with transparent particles of matter, each of said particles of matter being completely surrounded by said photoconductive material.

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