Feb. 9, 1965 TADAO KOHASHI 3,169,192

NEGATIVE PICTURE RADIATING APPARATUS

Filed May 10, 1961 2 Sheets-Sheet 1

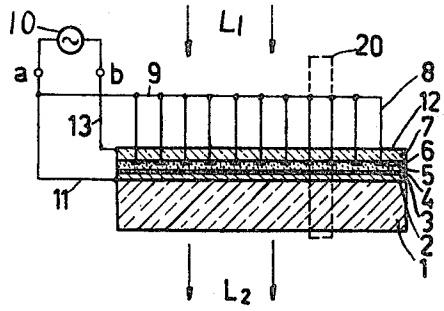

FIG.1

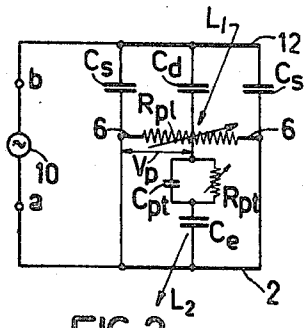

FIG.2

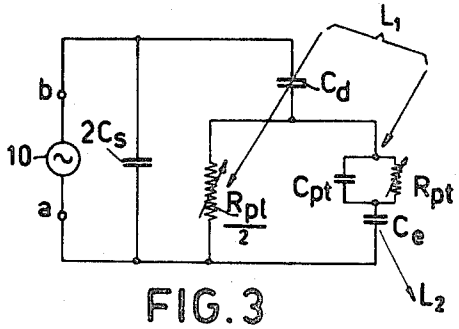

FIG.3

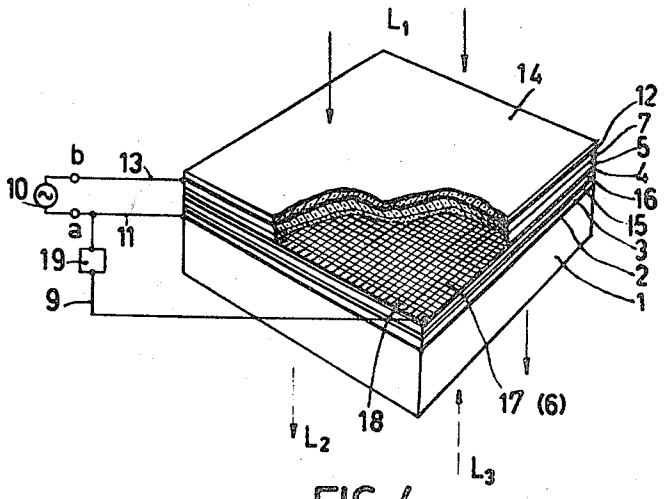

FIG.4

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NEGATIVE PICTURE RADIATING APPARATUS

Filed May 10, 1961 2 Sheets-Sheet 2

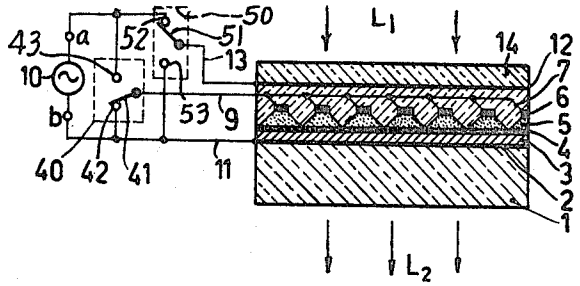

FIG.5

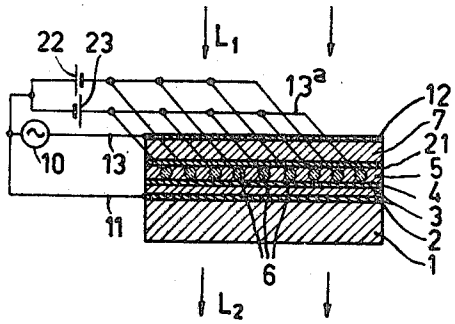

FIG.6

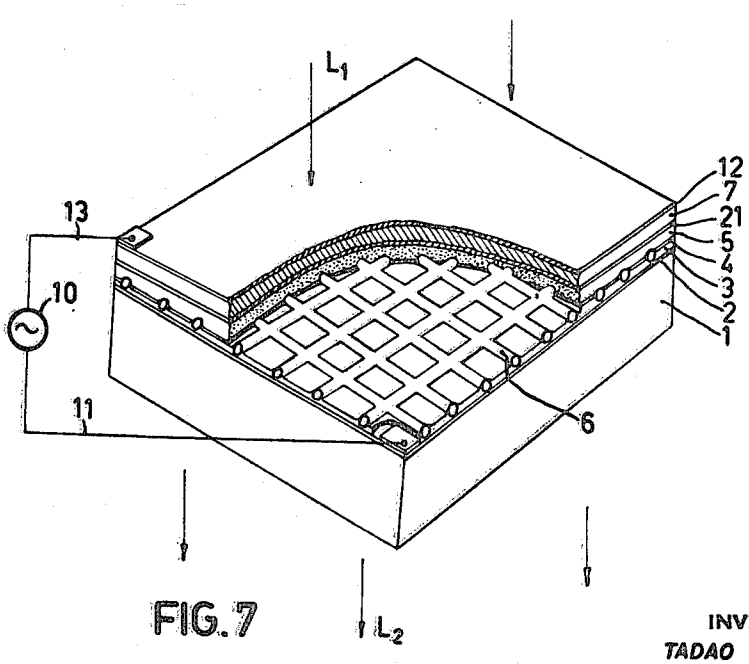

FIG.7

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NEGATIVE PICTURE RADIATING APPARATUS

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3 Claims. (Cl. 250—213)

The invention relates to a solid-state image intensifier comprising electrodes to be connected to a supply voltage source, which comprises a luminescent layer with a luminance varying with the electric field intensity therein, a first electrode on one side and a photo-conductive layer on the other side of this luminescent layer, and a radiation-pervious neutral impedance element on the side of the photo-conductive layer remote from the luminescent layer, these impedance elements being provided on the side remote from the photo-conductive layer with a second electrode.

Two in principle differing types of solid-state image intensifiers are known; in the first a luminescent element is controlled by a photo-conductive element electrically connected in series therewith, and in the second type a luminescent elment and a photo-conductive element are each time electrically connected in parallel with each other and as such connected in series with a neutral impedance element. When the luminescent elements in the intensifier are electro-luminescent elements, so that they exhibit an increasing luminance with an increasing electric field intensity therein, the first type of image intensifier reproduces a positive image and the second type reproduces a negative image of the primary radiation image projected onto the photo-conductive elements. On the other hand, the luminescent elements of the intensifier may be such that they exhibit the phenomenon of field quenching, i.e. an electric field produced in these elements quenches to a greater or smaller extent the luminescence produced therein by a suitable radiation, for example ultraviolet radiation, the quenching effect being the greater the higher is the intensity of the field. When the solid-state image intensifiers of the said types are equipped with luminescent elements of the latter kind, image inversion occurs in the first type, whereas the second type produces a positive image.

The invention relates to a solid-state image intensifier of the second type; however by connecting the electrodes in a given manner to the supply voltage source an intensifier according to the invention may be employed as an intensifier of the first type.

In accordance with the invention, the photo-conductive layer is provided with a third electrode, which has the form of a grid, while the second electrode is arranged at least above the openings of the third electrode, the openings of the third electrode having a size such that, when the first electrode and the second electrode are connected to the terminals of a supply voltage source, whereas the third electrode is coupled with the first electrode or with a tapping of the said voltage source, the potential of which tapping lies between that of the first electrode and that of the second electrode, in the state of minimum conductivity of the photo-conductive layer an electric field passes through the openings of the third electrode and determines the luminance of the luminescent layer occurring in the luminescent layer, of which field the intensity decreases with increasing conductivity of the photo-conductive layer. The effect of the third electrode in the solid-state image intensifier according to the invention may be compared to some extent with that of a control-grid in an electron tube, on the understanding that in the image intensifier the electrical extension of this control-grid can

be locally varied by radiation impinging on the photo-conductive layer.

In a further development of the invention, the third electrode is preferably formed by interconnected, linear, equidistant, good conductive elements, in particular, by parallel extending, conductive wires. In the last-mentioned case it is advantageous to make the conductive wires from metal. In accordance with the invention it is also possible to form the third electrode from a metal, net-shaped grid, which has more or less rectangular meshes, of which the length and the width are approximately the same.

It should be noted that a solid-state image intensifier of the aforesaid second type is known, which, as in the intensifier according to the invention, comprises three electrodes, however, in this known intensifier the third electrode is interlacedly arranged with the second electrode on the neutral impedance elements on the side remote from the photo-conductive layer. The solid-state image intensifier according to the invention, as compared with this known image intensifier, has the advantage of a greater sensitivity and is suitable for a higher supply voltage while the construction may for the rest be the same; this results in a better visible image. Moreover, in the solid-state image intensifier according to the invention, the third electrode, which is in electrical contact with the photo-conductive layer, may consist of two electrically separated groups of alternating linear electrodes, which groups are connected to each other and to the supply voltage source via direct-voltage sources of opposite polarities. When the photo-conductive layer consists of a photo-conductive powder and a binder, this results in a higher sensitivity.

The invention will now be described with reference to the drawing, which shows a few embodiments. In the drawings:

FIG. 1 shows diagrammatically a cross sectional view of a first embodiment and

FIG. 2 shows an electric diagram of a group of elements of the intensifier of FIG. 1, which elements in co-operation, define an image point of the reproduced image.

FIG. 3 shows the same electric diagram, now in a form easier to understand.

FIG. 4 shows in isometric projection a second embodiment of the solid-state image intensifier according to the invention, parts of various layers being omitted.

FIG. 5 shows a cross sectional view of a further embodiment of the image intensifier according to the invention, in which the possibility of a switch-over of the electrodes is indicated to use the intensifier at will as an intensifier of the first type or of the second type.

FIG. 6 shows diagrammatically a cross sectional view of a third embodiment, in which the third electrode is formed by parallel metal wires.

FIG. 7 shows finally in isometric projection an embodiment in which the third electrode is formed by a net-shaped metal grid, which engages the first electrode. Also in this case parts of various layers are omitted.

The various embodiments to be described comprise for a large part practically identical components, which accordingly are designated by the same reference numerals. It should furthermore be noted that many dimensions, for example various values of thickness, are not shown in the figures in the correct ratio. If necessary, suitable dimensions are indicated hereinafter by the numerical values.

In the solid-state image intensifier shown in FIG. 1 a transparent supporting plate 1 of glass is provided with a flat, transparent electrode 2 (first electrode), which may consist, for example, of conductive tin oxide. On the electrode 2 extends a luminescent layer 3 which consists of electro-luminescent material, for example zinc-oxide activated with copper and comprising aluminum as co-activator and a synthetic resin, for example an epoxy,

a polystyrene, or an urethane resin, as a binder. The thickness of the layer 3 is approximately 70μ. On the layer 3 is provided a thin, light-screening layer 4, which may consist of finely divided carbon and a binder, for example one of the aforesaid synthetic resins. The thickness of the layer 4, which may, for example, be about 10μ and the composition of the layer 4 must be such that the electrical resistance of this layer in its plane is not too low, since otherwise the image definition may be affected adversely. Instead of using a single layer 4 of carbon and a binder, use may be made of a bipartite screening layer 4, in which case the luminescent layer 3 has directly applied to it a thin, reflecting layer, for example, of titanium dioxide and a binder, on which a thin layer of carbon and binder material is provided. The light-screening layer 4 serves to prevent light from the luminescent layer 3 from affecting the photo-conductive layer 5 on the layer 4 in an undesirable manner. This photo-conductive layer 5 consists of a photo-conductive powder, for example cadmium sulphide (activated with copper and chlorine), cadmium selenide or such like, and a binder, for example one of the aforesaid synthetic resins, and it has a thickness of about 50μ.

The photo-conductive layer 5 is provided on the side remote from the screening layer 4 with an electrode 6 (third electrode), which consists of a plurality of equidistant, linear elements, which are electrically connected to each other. These linear elements may consist of metal and may be applied by vaporisation. As an alternative, they may consist of a conductive lacquer, for example, silver powder with resin, for instance a thermo-hardened resin.

On the photo-conductive layer 5 with the electrode 6 extends a layer 7 which is pervious to radiation and which is made of a material having low dielectric losses. The layer 7 may consist, for example, of a transparent synthetic resin, for example one of the aforesaid resins, or it may be formed by a glass plate. The thickness of the layer 7 depends upon the dielectric constant of the material of the layer, on the impedances in the direction of thickness of the subjacent layers and on the relative distance between the parallel elements of the electrode 6, as will be explained more fully hereinafter. The top side of the layer 7 is provided with a transparent, flat electrode 12 (second electrode) which may be obtained by applying by vaporisation a thin layer of aluminum, gold or other suitable metal or else by coating this side of the layer 7 with a thin layer of conductive lacquer obtained by mixing silver powder with a binder, for example a thermo-hardening resin. If the layer 7 is made of glass, the electrode 12 may consist, in known manner, of a conductive oxide, for example tin oxide. If the layer 7 is formed by an independent glass plate or foil, the contact with the photo-conductive layer 5 may be obtained with the aid of an adhering layer of, for example, a synthetic resin; instead a thin layer of an insulating liquid with low dielectric losses, for example, silicone oil may be interpositioned and the layer 7 may then be held by pressure on the layer 5.

In order to use the solid-state image intensifier described as an intensifier of the aforesaid second type, the electrodes 2 and 12 are connected via the conductors 11 and 13 respectively to the different terminals *a* and *b* of an alternating-voltage source 10. The electrode 6 is connected via the conductor 9 to the same terminal, i.e. terminal *a* of the source 10, to which the electrode 2 is connected. When a primary radiation image is projected through the electrode 12 and the transparent layer 7 onto the photo-conductive layer 5 (this image is symbolically indicated in the figures by L_1), which layer 5 is thereby rendered locally more or less conductive in accordance with the local intensity of the primary radiation image, the electro-luminescent layer 3 will produce through the electrode 2 and the supporting plate 1 an inverse or negative image corresponding to the primary image, i.e. an image of which the brightness is inverted (the image reproduced by the intensifier is indicated by the symbol L_2), it being assumed that the voltage supplied by the source 10 to the electrodes is sufficiently high for the electro-luminescent layer 3 to luminesce more or less uniformly, when the photo-conductive layer 5 is not irradiated. This operation of the image intensifier of FIG. 1 is explained with reference to FIGS. 2 and 3, which show the electric equivalent circuit diagram of a group of superimposed elements of the various layers which elements are located between two successive parallel linear parts of the electrode 6. Such a group of elements, designated by 20 in FIG. 1, determines the size of an image point of the luminescent image reproduced by the layer 3. The size of this group in the direction transverse to the plane of the drawing is approximately equal to the dimension in the plane of the drawing parallel to the luminescent layer 3, i.e. equal to the spacing of the parallel parts of the electrode 6. In the electric equivalent diagram of the group 20 shown in FIG. 2 the current circuit elements are shown as lumped impedances, whereas actually the circuit comprises distributed impedances. In this diagram the electrical screening effect of the parallel parts of the electrode 6 is not indicated. In FIG. 2 the capacitors C_s represent the capacity between the electrode 12 and a segment of the electrode 6. The resistance R_{pl} represents with omission of the parallel capacity the part of the photo-conductive layer 5 lying between the successive parts of the electrode 6. C_{pt} and R_{pt} designate the impedance of this part of the photo-conductive layer in the direction of thickness thereof, C_{pt} is the capacity and R_{pt} is the resistance. The impedance in the direction of thickness of the electro-luminescent layer 3, while the resistance is neglected, is designated by C_e, the resistance of this layer being omitted. The impedance of the light screening layer 4 is neglected, but it may, of course, be considered to be included in the capacity C_e. The impedance between the parts of the electrode 6 and the electrode 2 is also omitted, since these electrodes are externally connected electrically to each other.

FIG. 3 shows, in principle, the same diagram, but in a way more suitable for understanding its performance. The two diagrams show clearly that in each elementary group 20 of the image intensifier of FIG. 1 an element of the luminescent layer 3 with a capacity C_e is connected in series with the impedance (measured in the direction of thickness) of an element of the photo-conductive layer 5, which impedance comprises the parallel combination of the capacity C_{pt} and the resistance R_{pt}. With this series combination is connected in parallel half the resistance of the photo-conductive element measured in the direction of its plane, i.e. $R_{lp}/2$. This parallel combination of elements of the photo-conductive lever 5 and an element of the luminescent layer 3 is connected electrically in series with the impedance of an element of the layer 7, indicated as the capacity C_d, existing between the electrode 12 and the element concerned of the photo-conductive layer 5. To this series combination is applied the alternating voltage supplied by the source 10, which is also supplied to the capacities C_s. It will appear that an image intensifier of the aforesaid second type is concerned here, i.e. an intensifier in which the reproduced image L_2 is the inverse of the primary radiation image L_1. When the voltage of the voltage source 10 is chosen sufficiently high for the element having the capacity C_e to luminesce in the non-irradiated state of the photo-conductive layer 5, i.e. with a high value of $R_{pl}/2$, the photo-conductive layer will be rendered more or less conductive by the primary radiation image L_1, so that $R_{pl}/2$ decreases in accordance with the local radiation intensity and hence the distribution of the supply voltage among the capacity C_d and the parallel combination of $R_{pl}/2$ and C_e is varied so that the voltage across the capacity C_e decreases accordingly. The influence of

the impedance in the direction of thickness of the photo-conductive layer 5, represented by the parallel combination of C_{pt} and R_{pt}, is small or may be negligible, if this impedance is small with respect to the impedance formed by C_e. This may be achieved by correct proportioning of the layers 3, 4 and 5.

From FIG. 2 it is most clearly evident that the photo-conductive layer 5 operates in accordance with its conductivity as a more or less effective screen for the electric field extending from the electrode 12 via the capacitor C_e to the electrode 2, which field determines the luminance of the element of the luminescent layer 3, represented by C_e. The relative distance between the parallel parts of the electrode 6 is required to be such that, when the image intensifier is fed by not too low a voltage, which must of course lie below the break-down voltage, this electric field is capable of penetrating adequately between the parts of the electrode 6 in the non-irradiated state of the photo-conductive layer 5. On the other hand the relative distance between the parallel parts of the electrode 6 determines the image definition, so that this distance should not be chosen too large. Since the said electrode parts screen the directly subjacent parts of the luminescent layer 3 from the electric field, dark lines may be produced in the luminescent image L_2. This may be mitigated by choosing a minimum width of the parallel parts of the electrode 6; in this case, of course, the technological possibilities and an adequate conductivity of these parts are to be taken into account. The dimensions of the various layers being chosen as stated above, the image intensifier shown in FIG. 1 yields a satisfactory result, when the width of the parallel extending parts of the electrode 6 is 200μ and their spacing is about 500μ. In this case a thickness of the layer 7 of about 300μ is favored.

When in the intensifier shown in FIG. 1 luminescent light from the layer 3 is permitted to influence the conductivity of the layer 5, a negative (optical) feedback is produced, which reduces the sensitivity of the intensifier and causes, on the other hand, the characteristic curve, i.e. the relationship between L_2 and L_1 with a given supply voltage, to exhibit a lesser slope and hence to become more linear. The light-screening layer 4 serves to restrict this negative feedback and, if necessary, to suppress it completely.

The capacities C_s between the electrodes 12 and 6 are, as stated above, connected directly to the supply voltage source 10. If the layer 7 has comparatively high dielectric losses, this may give rise to a considerable development of heat, which may lead to a break-down. The capacities C_s may be reduced by not spreading the electrode 12 over the whole surface of the layer 7, this electrode being then formed, like the electrode 6, of electrically interconnected parts, extending above the interstices of the electrode 6 and parallel thereto. This means that those parts of the planar electrode 12 shown in FIG. 1 which are directly located above the parts of the electrode 6 are omitted. If desired, also the parts of the layer 7 directly above the parts of the electrode 6 may be omitted.

The embodiment of the solid-state image intensifier according to the invention shown in FIG. 4 differs from the embodiment shown in FIG. 1 in the following.

The luminescent layer on the electrode 2 is divided into two parallel extending part-layers 3 and 16, of which the part-layer 3 constitutes the output layer, which supplies the image L_2 to be observed and the part-layer 16 is a luminescent layer, providing an optical feedback to the photo-conductive layer 5. To this purpose the spectral emission curve of the part layer 16 should suitably overlap the spectral sensitivity curve of the photo-conductive layer 5. Between the layers 3 and 16 is sandwiched a thin, opaque layer 15, for example, of a mixture of very fine carbon powder and a synthetic resin,

which layer prevents light from the space where the luminescent image can be observed, symbolically indicated by L_3 in FIG. 4, from reaching the photo-conductive layer 5. The luminescent light of the layer 16 reaches the photo-conductive layer 5 via a partly transparent layer 4 and the openings of the electrode 6, formed by an opaque net-shaped grid 17 with square meshes, and located underneath the photo-conductive layer 5. Since the net-shaped electrode 17 is opaque—this electrode may consist for example of a metal grid or of lines of conductive lacquer, for example silver powder with a synthetic resin to which finely divided carbon is added—a lateral stray of the feedback light from the luminescent layer 16 to the photo-conductive layer 5 is reduced, which favours the image definition. The optical feedback between the part layer 16 and the photo-conductive layer 5 may in the case of a large overlap of the emission curve and sensitivity curve of these layers be suitably restricted by interposition of a thin extra light-absorbing layer (not shown).

The net-shaped electrode 17 is provided along one side of the image intensifier with a strip-shaped current supply conductor 18, for example of opaque, conductive lacquer, which is connected via the supply wire 9 and an impedance 19 to the same terminal of the voltage source 10 as to which the electrode 2 is connected. The introduction of the impedance 19 into the supply conductor to the net-shaped electrode 17 results in that the screening effect of the electrode 17 counteracting the penetration of the electric field to the luminescent layer 3 is reduced. The same may be achieved by connecting the electrode 17 directly to a point of which the potential lies between that of the terminals of the voltage source 10, for example to a tapping of a voltage divider bridging the voltage source 10. This reduction of the screening effect of the grid 17, which may otherwise be utilized not only with the image intensifier of FIG. 1 but also with the embodiments to be described hereinafter (with the exception of the embodiment shown in FIG. 7), permits of reducing the width of the meshes or of the relative distance between the parallel parts of the electrode 6, which is in contact with the photo-conductive layer.

Instead of using a net-shaped electrode 17, use may be made of an electrode 6 formed by equidistant conductive lines, in which case a restriction of the stray radiation in the direction of the lines of the said electrode of the luminescent light emanating from layer 16 may be obtained by providing opaque insulating lines, transversely to the parallel extending lines at electrode parts so that also in this case an opaque net-shaped grid between the luminescent layer 16 and the photo-conductive layer 5 is obtained. When the electrode 6 has not the shape of a net but consists of parallel extending lines, only the screening effect of this electrode from the electric field to the luminescent layer is less.

When using a transparent synthetic resin as the material for the layer 7, it may be difficult to apply the transparent electrode 12 thereto. Therefore, in the embodiment shown in FIG. 4, the electrode 12 is applied to a glass plate or foil 14, which is subsequently bonded with the layer 7 by its surface bearing said electrode 12. The electrode 12 on the plate 14 consists preferably of conductive tin oxide.

A similar supporting plate 14 for the electrode 12 is employed in the embodiment shown in FIG. 5. This embodiment differs from that of FIG. 1 mainly in that the photo-conductive layer 5 is not formed by a layer of uniform thickness but by a plurality of parallel, comparatively thick ribs. Between these ribs substantially V-shaped grooves are left, which extend up to the light screening layer 4. The layer 7 obtained by joining the neutral impedance elements extends over these ribs and fills the grooves therebetween. The line-shaped parts of the electrode 6 are applied to the tops of the photo-conductive ribs. The electrode 6 is connected via the con-

ductor 9 to the movable contact 41 of a switch 40, of which the stationary contacts 42 and 43 are connected to the terminals *b* and *a* respectively of the voltage source 10. The electrode 12 is connected in a similar manner via the conductor 13 to the movable contact 51 of a switch 50, of which the stationary contacts 53 and 52 are also connected to the terminals *b* and *a* respectively of the voltage source 10. These switches 40 and 50 permit of using the image intensifier shown in FIG. 5 at will as an image intensifier of the first type (series combination of photo-conductive elements and luminescent elements) or as an image intensifier of the second type (the parallel combination of photo-conductive elements and luminescent elements series connected with neutral impedance elements). In the position shown in FIG. 5, in which the switch 40 connects the electrode 6 to the terminal *b* and hence also the electrode 2, and the switch 50 connects the electrode 12 to the terminal *a*, the image intensifier shown operates as an intensifier of the second type. After change-over of the switches 40 and 50, so that the electrode 6 is connected to the terminal *a* and the electrode 12 to the terminal *b* (with which the electrode 2 remains connected), the image intensifier operates as an intensifier of the first type. The impedance formed by parts of the layer 7 between the electrodes 6 and 12 are then directly connected to the voltage source 10.

In order to obtain an image intensifier of the first type it is, however, not strictly necessary for the contact 53 of the switch 50 to be connected to the terminal *b* of the voltage source 10. The contact 53 could be left unconnected, so that the impedance between the electrodes 6 and 12 does not constitute a load for the voltage source. On the other hand, this would involve the risk of cross-talk between the photo-conductive elements associated with different elementary groups, said cross talk occurring via the impedances between these elements and the electrode 12, which is common to these elementary groups.

The change-over of the connections of the electrodes 6 and 12 to the voltage source 10 may be carried out also in the other embodiments, described herein, however with the exception of the embodiment shown in FIG. 7.

In the embodiment shown in FIG. 6 the electrode 6 consists of a plurality of parallel wires, embedded in the photo-conductive layer 5. These conductive wires, which have the same thickness (about 50μ) as the photo-conductive layer 5, consist preferably of metal, for example, brass, tungsten or steel; however, they may consist alternatively of textile yarn or synthetic resin yarn provided with a conductive coating, for example of conductive lacquer. The wires of the electrode 6, which are spaced apart by a distance of about 500/μ, are alternately connected to each other, so that two electric groups of electrode wires are obtained. One group is connected via a direct-voltage battery 22 and the other group is connected via a direct-voltage battery 23 to that terminal of the voltage source 10 to which also the electrode 2 is connected. The direct-voltage sources 22 and 23, viewed from the alternating-voltage source 10, have opposite polarities. This circuit arrangement ensures that the elements of the photo-conductive layer 5 consisting of a photo-conductive powder and a binder are fed by a pulsatory direct voltage, whereas the luminescent layer 3 is fed by alternating voltage. The reason thereof is that a photo-conductive element consisting of a photo-conductive powder and a binder is more sensitive when fed by direct voltage, than when fed by alternating voltage.

The image intensifier shown in FIG. 6 may be constructed as follows. The supporting plate 1 is provided in order of succession with the transparent electrode 2, the luminescent layer 3 and the light screening layer 4, the latter being adapted to restrict or completely suppress the optical feedback. Then this assembly is provided with a plurality of V-shaped grooves, for example of a depth of 2 mms. along two opposite longitudinal edges with the aid of a cutting or grinding tool, the grooves being spaced in accordance with the desired distance between the wires of the electrode 6. The support 1 with the various layers applied thereto is then provided with a helically wound wire adapted to form the electrode 6, said wire being arranged with adequate tension in the said grooves. The turns of the wire are secured along the edges of the support 1 by means of a thermo-hardening, conductive layer, obtained, for example, by mixing silver powder with an epoxy resin. After the turns have been secured in place, the parts thereof lying on the side of the support 1 remote from the electrode 2 are cut through and removed. The photo-conductive layer 5 is then applied to the wires stretched over the light screening layer 4, for example by applying a suspension of photo-conductive powder, a synthetic resin and a suitable solvent by means of a silk-screening method to the face provided with the wires of the electrode 6 (screen printing of the photo-conductive layer). After the silk screen has been removed, the solvent is evaporated from the photo-conductive layer, which thereupon is bonded with the aid of an adhering layer 21, for example of a synethetic resin, with the neutral impedance elements united to form an uninterrupted layer 7. The layer 7, which may consist, for example, of a glass foil, is provided on the side remote from the photo-conductive layer 5 with the planar electrode 12, which is transparent and consists preferably of conductive tin oxide.

Instead of winding a conductive wire around the support 1 with the layers 2, 3 and 4 applied thereto to obtain the electrode 6, the wire may first be wound with the correct intermediate space on a separate tensioning frame, having for example two metal bars provided with screw-thread having a pitch equal to the desired distance between the wires, after which the grid thus formed or the grid consisting of the appropriate halves of each turn thereof is stretched over the layer 4 and the wires are fixed to the edge of the support 1 after which the grid is cut loose from the frame and the photo-conductive layer is printed in the manner described above into the interstices of the grid extending over layer 4.

The electrode 6 may be formed not only by parallel, equi-distant wires but as an alternative also by a net-shaped grid. To this end first a net-shaped grid is provided on a frame and then stretched over the light screening layer 4, after which the aforesaid process is carried out.

It is not necessary for the conductors of the electrode 6 to have the same thickness as the photo-conductive layer 5. With a view to the penetration of the primary radiation image (L_1) into the photo-conductive layer 5, it is advantageous, in the case of a thinner electrode 5, not to apply this electrode immediately over the light screening layer 4, but to provide it in or on the surface of the photo-conductive layer facing the electrode 12. Thinner wires of the electrode 6 have the advantage that their "shadow"-effect is reduced and that their relative distance may be smaller, so that a better image definition is obtained. In such a case the light screening layer 4 is first provided with a part of the photo-conductive layer of a thickness of, for example 30μ. Thereon is stretched the electrode 6, consisting of thin, parallel wires or formed by a net-shaped grid and the interstices of this electrode are filled out by the remaining part of the photo-conductive layer 5. Both the application of the first part of the layer 5 and the filling process may be carried out as before by screen printing. In this case use may be made for the electrode of a net-shaped grid of the kind used in a television camera tube of the vidicon type or a memory storage tube. Such a net-shaped grid may have a thickness of 8μ and may have mesh dimensions of 50μ by 150μ.

The photo-conductive layer 5 may also consist of sintered, photo-conductive material, for example sintered cadmium sulphide or cadmium selenide, the latter responding more rapidly to radiation than cadmium sulphide. For the manufacture of an image intensifier ac-

cording to the invention comprising such a sintered, photo-conductive layer the following method may be carried out. The layer 7 consists of an independent plate or foil of a transparent material having a high melting point, for example high-melting-point glass or the material known as Pyroceram. Over one side thereof is stretched an electrode 6 of parallel wires or formed by a net-shaped grid of a high-melting point metal, for example tungsten. To this electrode is applied a thin layer of cadmium sulphide or cadmium selenide powder, after which this layer is sintered at a temperature of about 600° C. in a suitable gas atmosphere, for example air or nitrogen. Then the electrode 12 may be arranged on the other side of the plate 7 and the plate thus obtained may be bonded by an adhering layer with the further part of the image intensifier comprising the layers 1, 2, 3 and 4. The binder of the layers 3 and 4 may be glass enamel, so that the various layers can be satisfactorily bonded to each other by a thermal treatment (this applies, of course, also to the other embodiments). The layers 4, 3, 2 and 1 may, as an alternative, be applied in order of succession to the sintered, photo-conductive layer.

In the embodiment shown in FIG. 7 the electrode 6 of the photo-conductive layer 5 is formed by a net-shaped grid which is in direct contact with the electrode 2 and of which the wires have a thickness which is at least equal to the thickness of the luminescent layer 3. This layer 3 consists of elements filling out to a greater or smaller extent the meshes of the grid-shaped electrode 6. On the elements of the layer 3 are arranged the elements of the light screening layer 4. Over the electrode 6 and the screening layer 4 extends the photo-conductive layer 5, of which the other side is in contact via the bonding layer 21 with the neutral impedance elements united to form an uninterrupted layer 7. The top sides of the wires of the electrode 6 reach into the photo-conductive layer 5; if these top sides are coated with a very thin layer of luminescent material and/or material of the light screening layer 4, this is little harmful if the image intensifier is fed by alternating voltages. If necessary, the top side of the electrode 6 may be cleaned, for example by means of a planing tool, prior to the application of the photo-conductive layer.

It is not necessary for the electrode 6 to consist of parallel wires or wires united to form a grid. As an alternative, the support 1 with the electrode 2 may first be provided with an uninterrupted luminescent layer 3 and subsequently with a light screening layer 4 thereon, in which subsequently parallel grooves or grooves forming a grid having substantially square meshes are cut and then filled with a preferably opaque, conductive lacquer. The capacity of the electrode 6, whether it is formed by metal wires or opaque, conductive lacquer, has the advantage that the optical feedback by the luminesence light of the luminescent layer 3 emitted in the direction towards the photo-conductive layer is spatially restricted.

In the embodiments described above it has been indicated that the luminescent layer 3 is supplied with alternating voltage. The invention is also useful with solid-state image intensifiers in which the luminescent elements respond to direct voltage. In this case, however, care must be taken that the various layers have adequate direct-current conductivity in the direction of thickness, so that they must not be capacitatively operative only.

The material of the luminescent layer referred to by way of example is an electro-luminescent material. It will be obvious that without changing the principle, a luminescent material may be used in these elements which has field quenching properties. In the operation of a solid-state image intensifier according to the invention having such a luminescent material, provision must, of course, be made of an auxiliary source of radiation, which is capable of causing the luminescent elements to luminesce.

The solid-state image intensifier according to the invention need not only be suitable for working a primary radiation image formed by radiation in the visible part of the spectrum. The image intensifier may be useful for invisible radiation, for example infra-red, ultra-violet and X-ray radiations, provided the photo-conductive material in the layer 5 is chosen such to be capable of responding to this radiation and the electrode 12 and the material of the neutral impedance elements united in the embodiments shown to form an uninterrupted layer 7 are chosen such that they are pervious to the said radiation or do not absorb this radiation excessively.

What is claimed is:

1. A solid-state image intensifier comprising a first electrode, an electric-field-responsive luminescent layer over the first electrode, a radiation-responsive photo-conductive layer over the luminescent layer, radiation-unresponsive impedance elements over the photo-conductive layer, a second electrode over the impedance elements, a third electrode comprising spaced electrically-conductive portions defining intervening spaces, the lower portions of said third electrode contacting the first electrode and the upper portions of said third electrode contacting the photo-conductive layer, said luminescent layer extending to the spaces between the electrically-conductive portions of the third electrode, said second electrode having portions at least overlying the spaces in the third electrode, and means for applying a potential between the first and second electrodes, said spaces in the third electrode having dimensions at which, when the photoconductive layer is unirradiated, an electric field penetrates through the said spaces and determines the luminescence of the underlying portion of the luminescent layer, the intensity of said penetrating field varying inversely with the irradiation intensity of the photo-conductive layer.

2. A solid-state image intensifier as set forth in claim 1 wherein the third electrode comprises inter-connected equi distant linear portions.

3. An intensifier as set forth in claim 1 wherein the impedance elements form an uninterrupted transparent layer over the photo-conductive layer.

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