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Cusano

[11] **3,838,273**

[45] **Sept. 24, 1974**

[54] **X-RAY IMAGE INTENSIFIER INPUT**

[75] Inventor: **Dominic A. Cusano,** Schenectady, N.Y.

[73] Assignee: **General Electric Company,** Schenectady, N.Y.

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[21] Appl. No.: **257,538**

[52] **U.S. Cl.** .... **250/213 VT,** 250/483, 250/486

[51] **Int. Cl.** **H01j 31/50**

[58] **Field of Search** ..... 250/213 VT, 483, 486, 487, 250/488

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Primary Examiner—Archie R. Borchelt
Attorney, Agent, or Firm—Louis A. Moucha; Joseph T. Cohen; Jerome C. Squillaro

[57] **ABSTRACT**

A barrier layer of an electrically conductive material such as indium oxide (In_2O_3), optically transparent to x-ray phosphor luminescence, is disposed between the phosphor layer and photocathode film of an x-ray image intensifier tube to provide sufficient electrical sheet conductance relative to the photocathode film. The barrier layer provides electron replenishment to the photocathode at all points of electron emission therefrom to thereby reduce potential drop laterally across the photocathode from the ring electrode to the center of the photocathode, and also minimizes surface irregularities on the phosphor layer to thereby significantly reduce electron-optic image distortion in the image intensifier tube.

6 Claims, 10 Drawing Figures

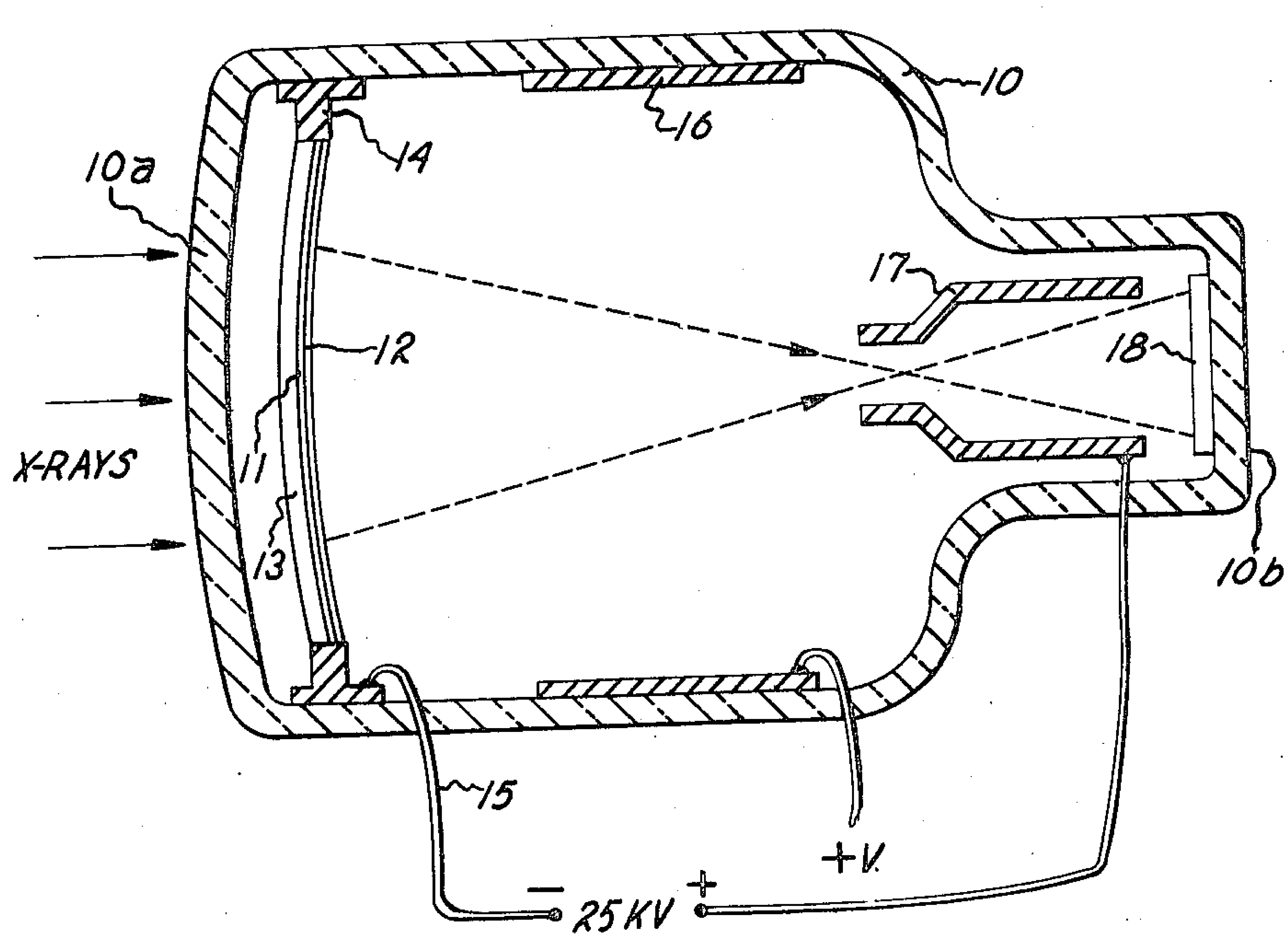


Fig.6

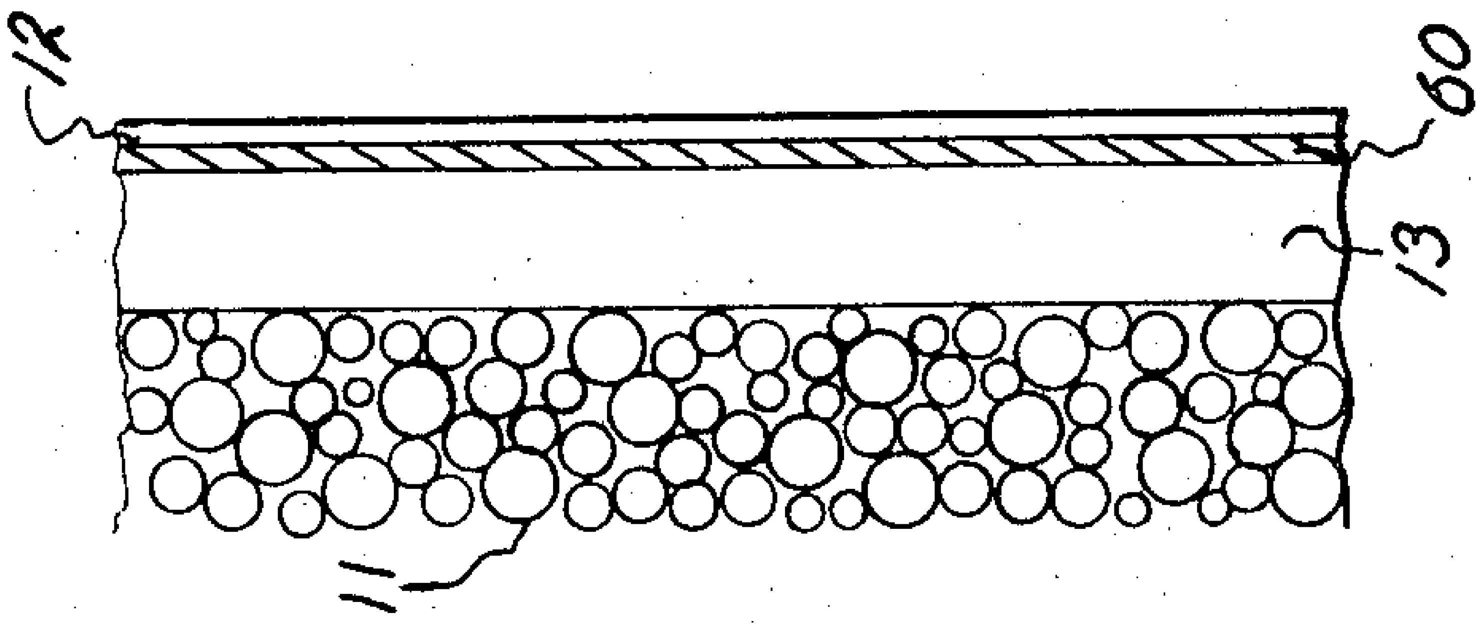
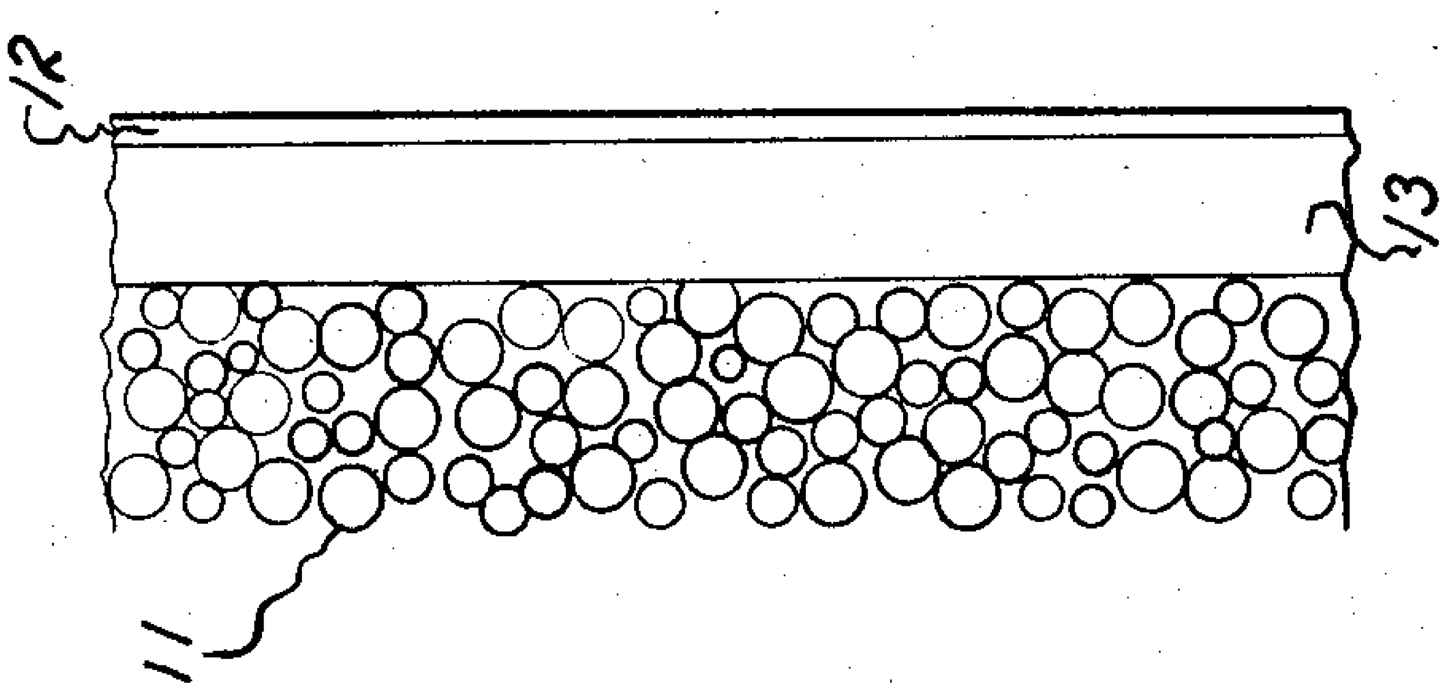
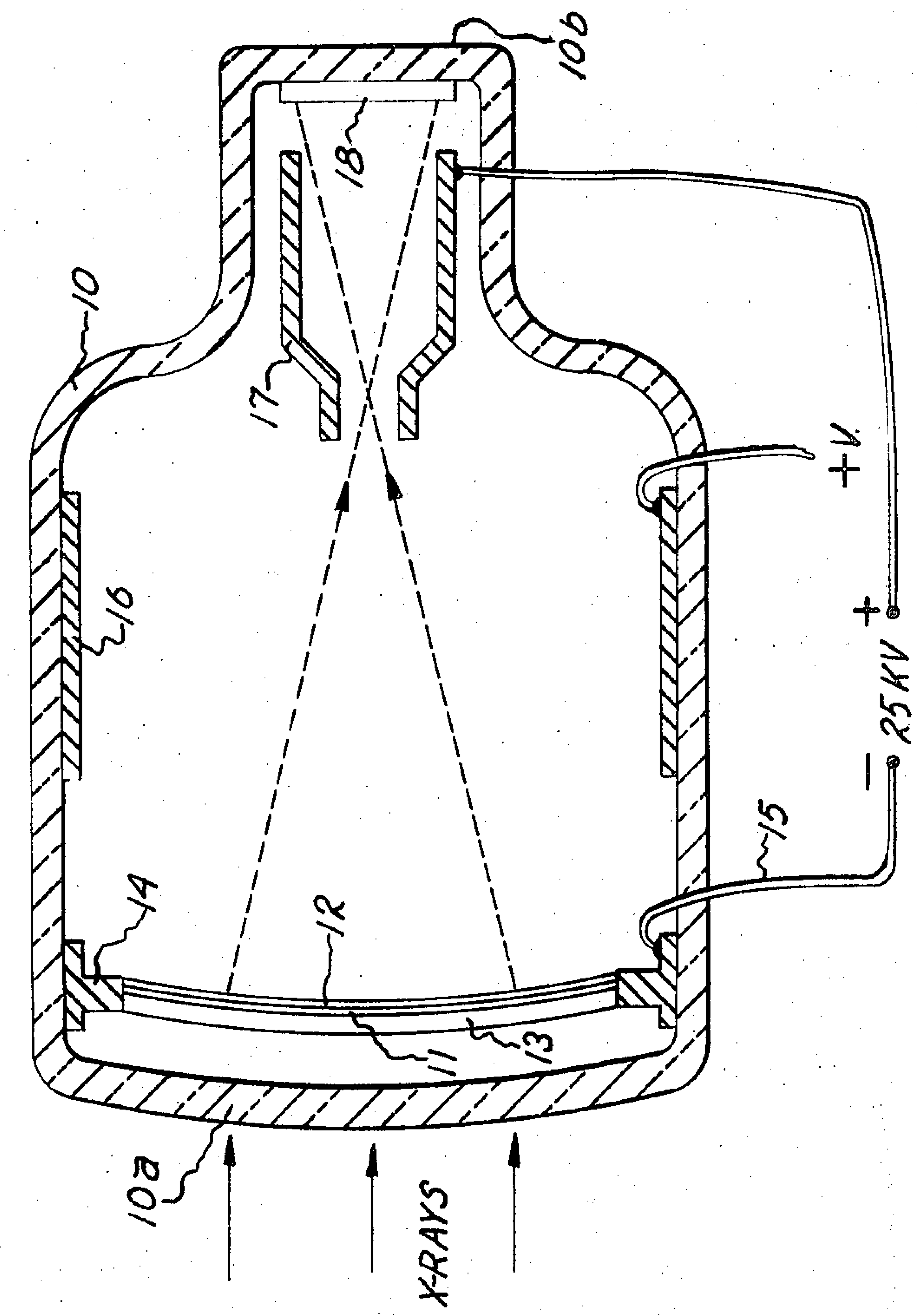


Fig.2



PRIOR ART

Fig.1



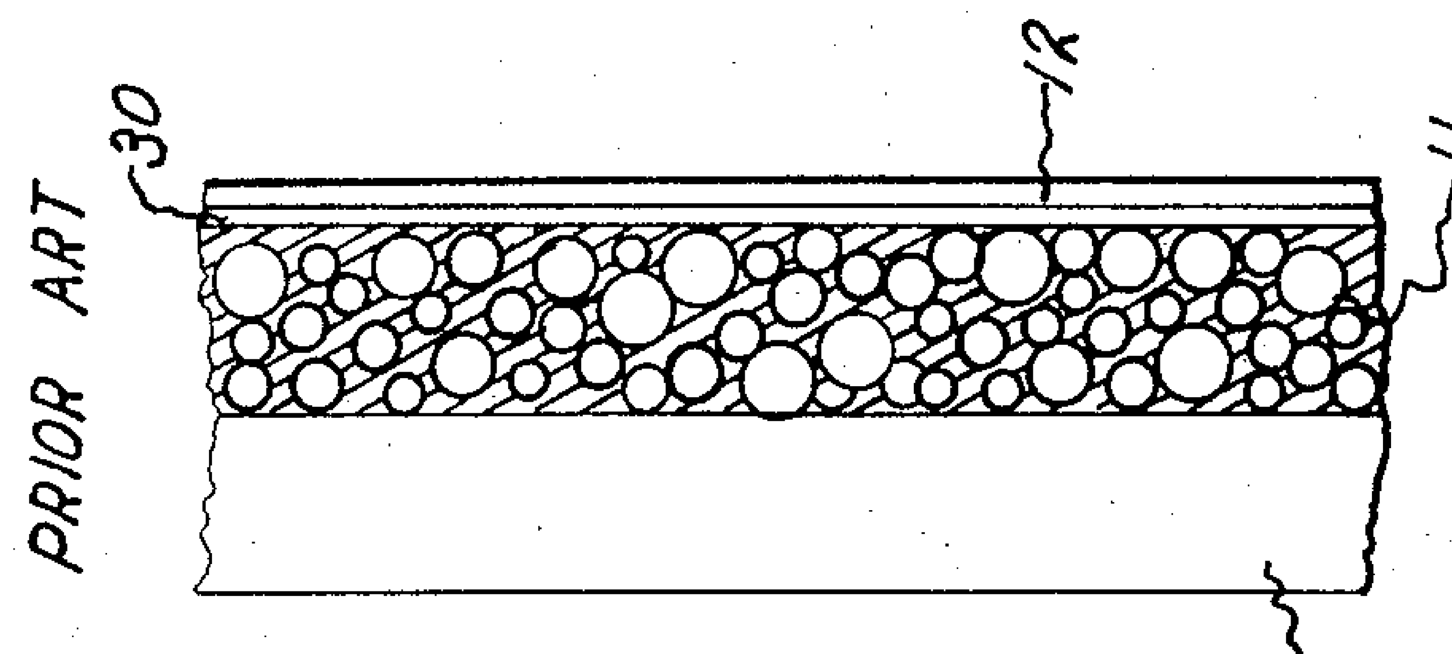


Fig.3

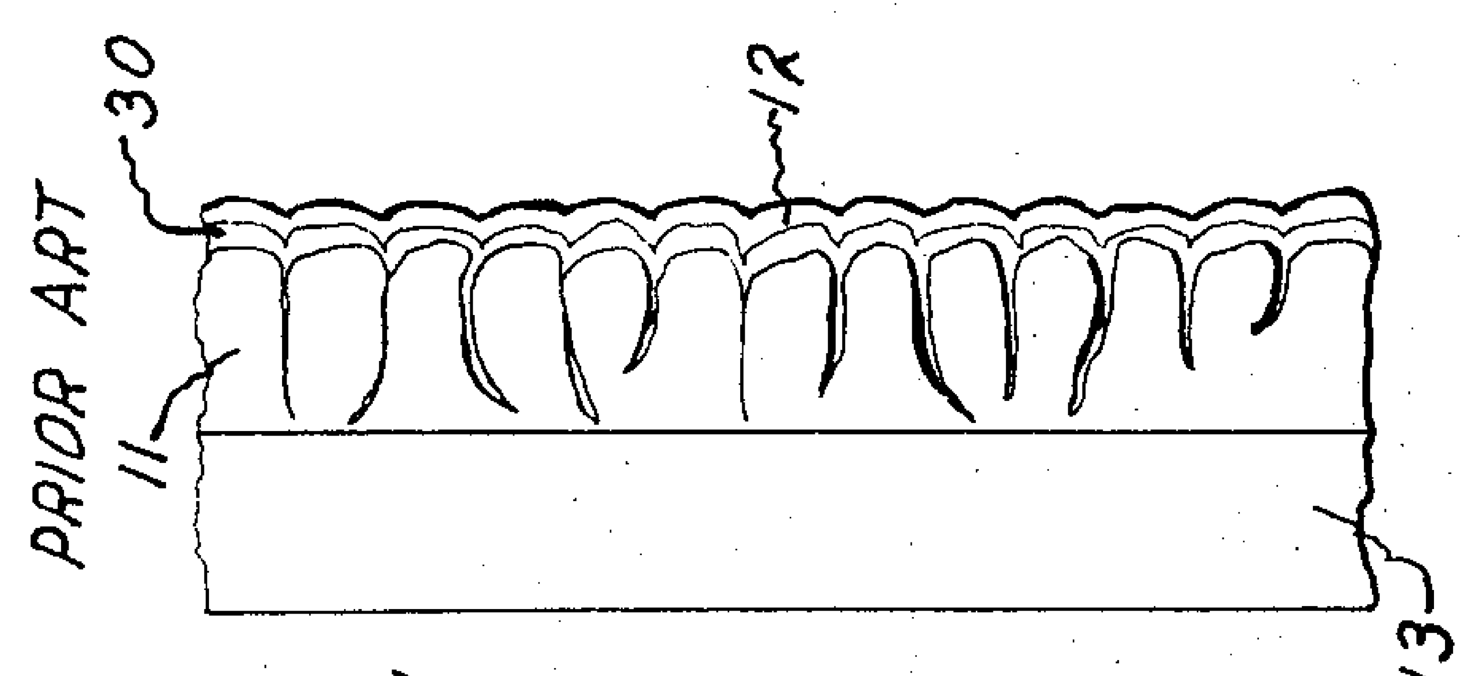


Fig.4

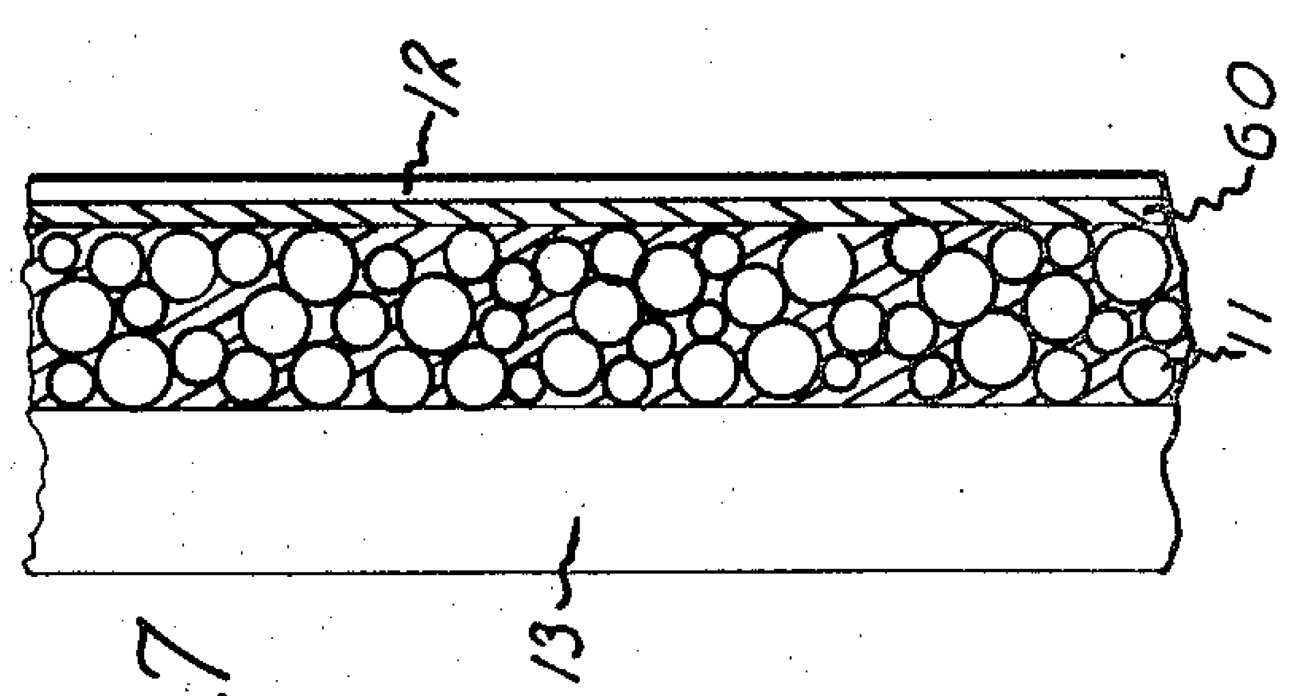


Fig.7

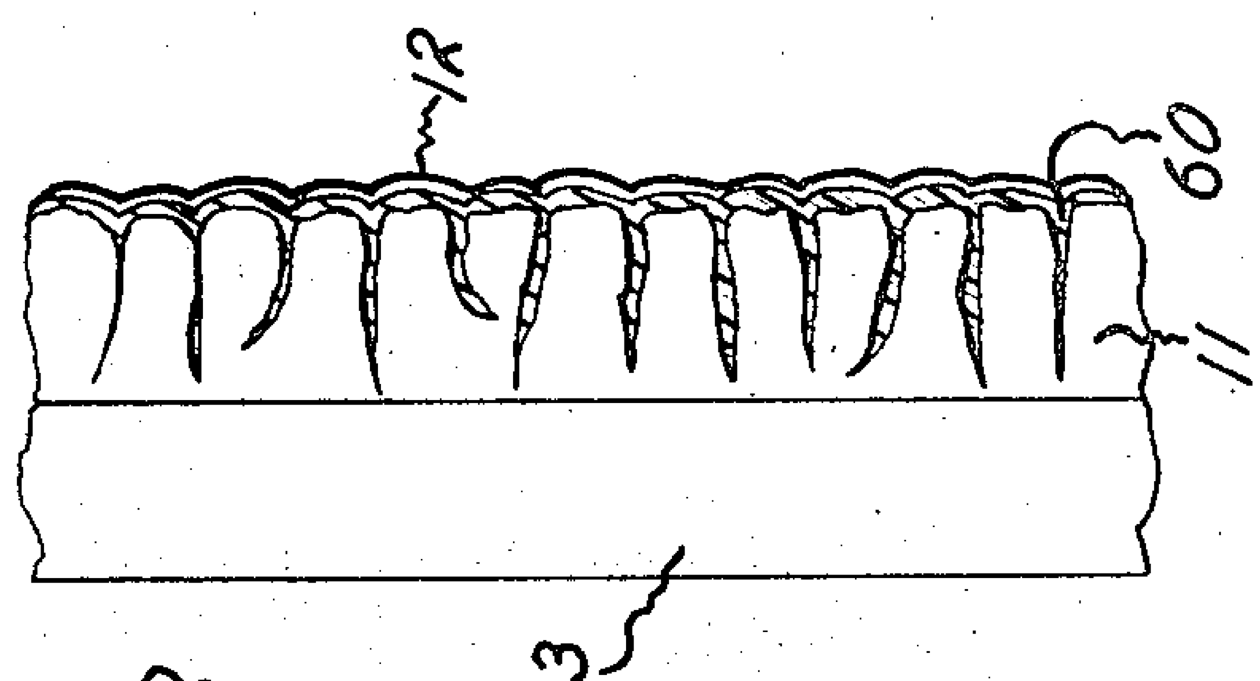


Fig.8

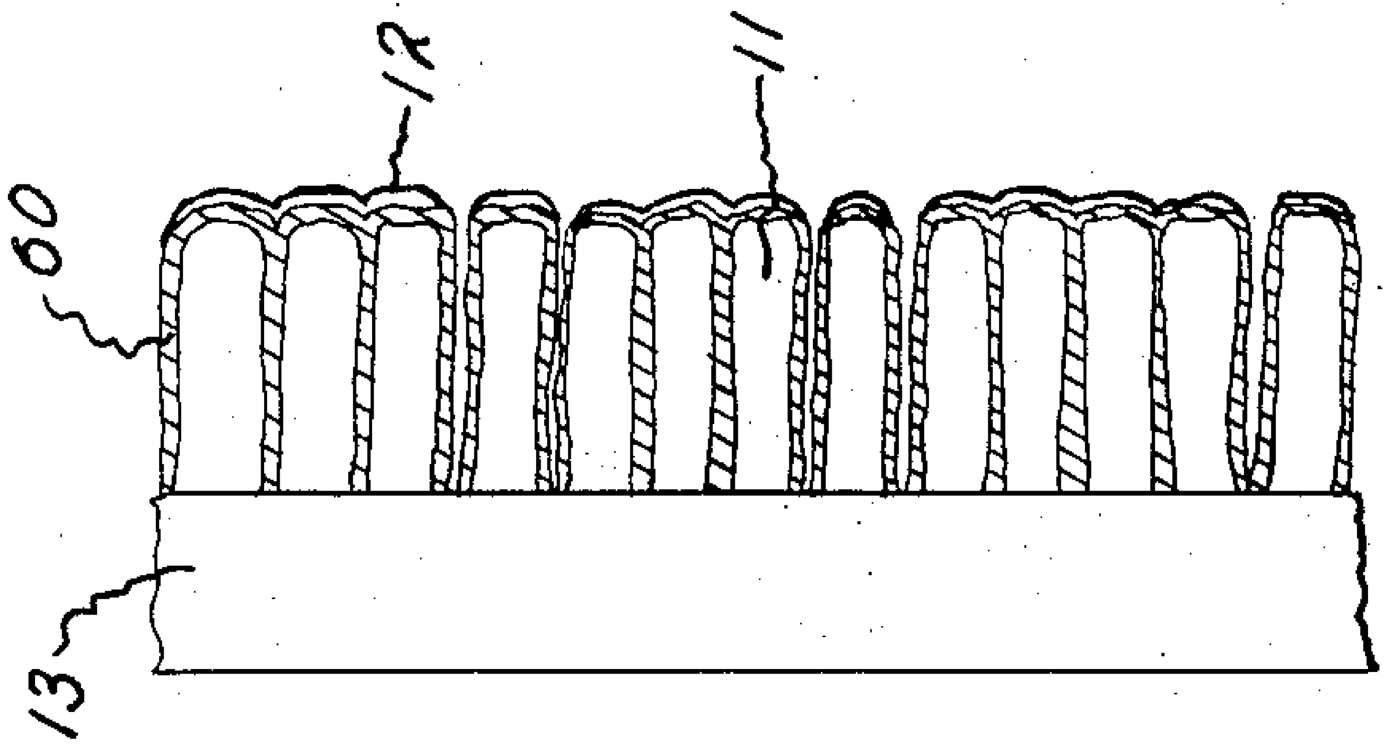


Fig.9

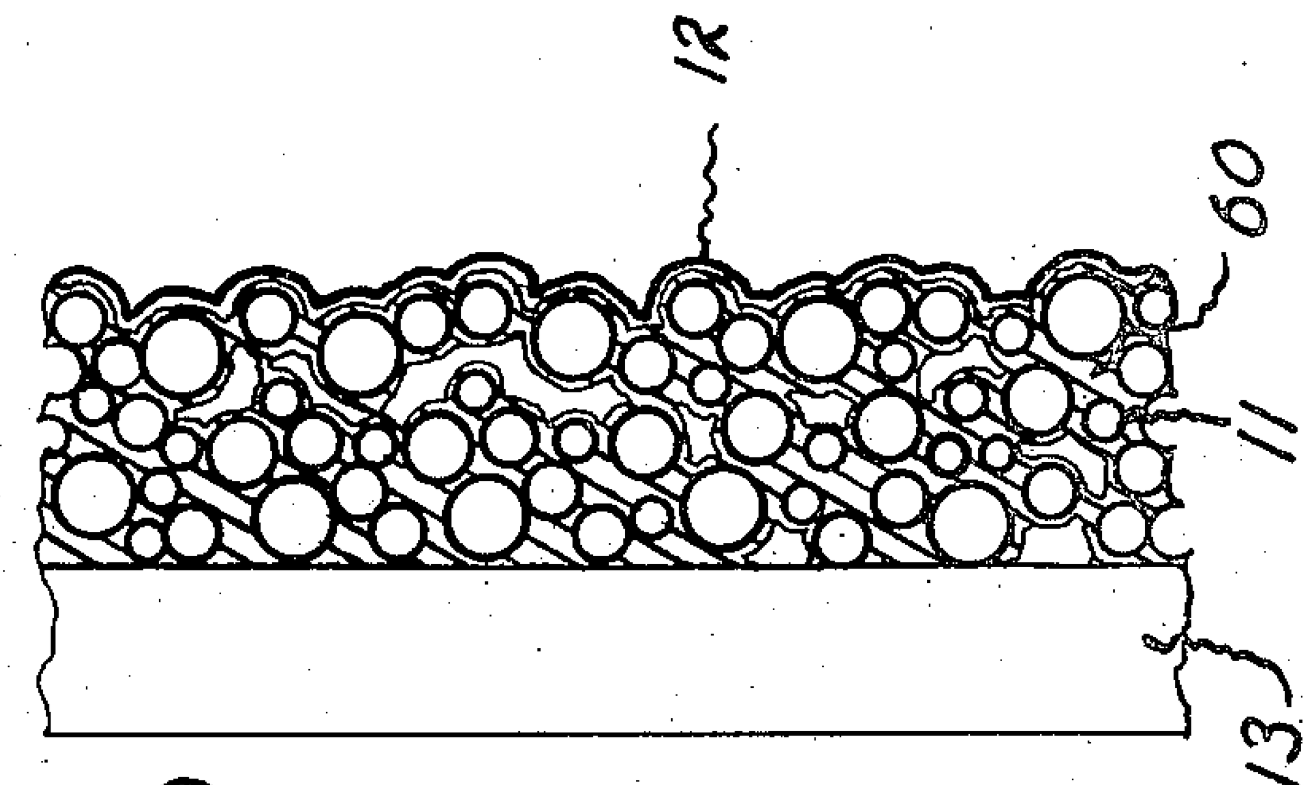
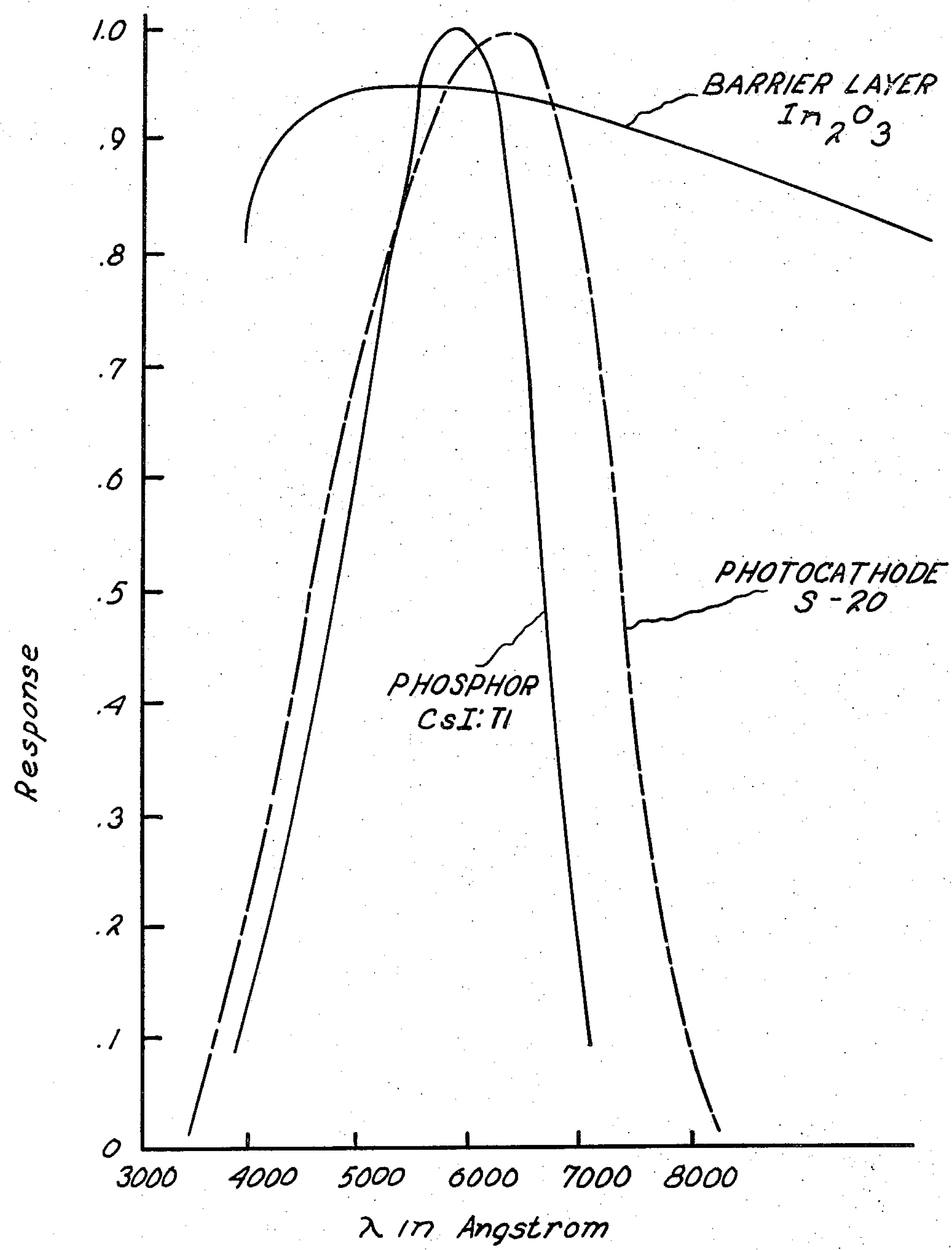


Fig.10

Fig. 5


1.0
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Response
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8000
λ in Angstrom
BARRIER LAYER
In2O3
PHOTOCATHODE
S-20
PHOSPHOR
CsI:Tl

X-RAY IMAGE INTENSIFIER INPUT

My invention relates to an x-ray image intensifier tube, and in particular, to an electrically conductive barrier layer in the input screen thereof.

The x-ray image intensifier tube is especially useful in the medical field for obtaining brighter x-ray images, particularly the images of body organs which generally are of low contrast. The conventional input screens of x-ray image intensifiers are of two types, a first employing a uniform layer of a dense high atomic number phosphor along a surface of a glass substrate adjacent the source of the x-ray photons for absorbing the incident x-rays which have traversed through a patient's body, and a thin photoemitting film deposited on the opposite surface of the glass substrate. The x-ray photons absorbed in the phosphor layer are converted to light photons in the order of approximately 1,000 light photons for each x-ray photon and emitted in all directions from the point of x-ray photon absorption. The light photons incident on the photocathode film are converted to photoelectrons and accelerated by means of an anode electrode and electron-optically focussed onto a second phosphor screen at the output end of the image intensifier in close proximity to the anode, resulting in a brighter image than at the input phosphor screen.

The second conventional input screen utilizes a substrate fabricated of glass or aluminum, and the phosphor layer is formed along the opposite surface of such substrate from the source of x-ray photons, and the photocathode film is deposited on the free surface of the phosphor layer.

Image intensifier tubes utilizing either of the hereinabove described input screens experience significant electron-optic image distortion resulting from symmetrical and uniform drops in the electrical potential of the photocathode film laterally thereof from the ring electrode to the center of the photocathode due to the high resistance of the photocathode. Further, with the second type of input screen, an electron-optic image distortion also arises due to a nonsymmetry, local variation in the photocathode potential due to the nonuniform thickness and nonuniform resistivity of the photocathode film resulting from the irregular surface of the phosphor layer on which the photocathode film is deposited.

In the case of the hereinabove second conventional input screen, it is conventional to deposit a thin barrier layer of an electrically insulating, phosphor luminescence transparent material between the phosphor layer and photocathode film in order to obtain chemical isolation therebetween. Such thin barrier layer results in only slight smoothing of the irregular surface of the phosphor layer and thus is only slightly effective in reducing the electron-optic image distortion due to the nonuniform thickness and resistance of the photocathode film, but it has no effect on the distortion arising from the uniform drop in potential laterally across the photocathode film. Also, there has been considerable difficulty in the prior art in suitably coupling a thick phosphor layer with a very thin photocathode film; and since the future trend in x-ray image intensifier technology appears to be toward even thicker phosphor layers or intentionally structured input phosphor screens for achieving higher image resolution and higher local image contrast, the phosphor layer-photocathode film interface problem will become even more acute.

Therefore, one of the principal objects of my invention is to provide an x-ray image intensifier tube having a new and improved input screen and which has substantially reduced electron-optic image distortion.

Another object of my invention is to provide an interface for efficiently coupling a thick phosphor layer with a very thin photocathode film.

A further object of my invention is to provide an interface between the phosphor layer and photocathode of future generation high resolution-high contrast input screens.

Briefly stated, and in accordance with my invention, I provide a barrier layer of an electrically conductive material which is optically transparent to x-ray phosphor luminescence and which functions as an interface between the phosphor layer and photocathode film of an x-ray image intensifier tube. The barrier layer material is compatible with both the phosphor and photocathode materials and provides chemical isolation therebetween and is sufficiently thick to provide substantial smoothing of irregularities on the surface of the phosphor layer. Most importantly, the significantly lower resistance of the barrier layer relative to the photocathode results in the barrier layer providing electron replenishment to the photocathode at all points of electron emission therefrom to thereby substantially reduce a uniform potential drop from the ring electrode to the center of the photocathode due to the high resistance of the photocathode film. The resultant reduction in uniform potential change laterally across the photocathode film as well as a reduction in nonuniform variation due to minimization of irregularities on the surface of the phosphor layer results in a significant reduction in electron-optic image distortion due to those factors in the image intensifier tube. A particularly suitable barrier layer material is indium oxide In_2O_3.

The features of my invention which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, however, both as to its orgainzation and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings wherein like parts in each of the several figures are identified by the same reference character, and wherein:

FIG. 1 is an elevation sectional view of a conventional x-ray image intensifier tube;

FIG. 2 is an enlarged elevation sectional view of a portion of a first conventional input screen in an x-ray image intensifier tube;

FIG. 3 is an elevation sectional view of a second conventional input screen;

FIG. 4 is an elevation sectional view of a relatively new type input screen utilizing evaporated phosphor material;

FIG. 5 is a graphical representation of the wavelength responses of the phosphor, barrier layer and photocathode materials of an input screen in accordance with my invention;

FIG. 6 is an elevation sectional view of the FIG. 2 input screen with the addition of a new barrier layer in accordance with my invention;

FIG. 7 is an elevation sectional view of the FIG. 3 input screen with the addition of my barrier layer;

FIG. 8 is an elevation sectional view of the FIG. 4 input screen with the addition of my barrier layer;

FIG. 9 is an elevation sectional view of a future generation input screen utilizing my barrier layer; and

FIG. 10 is an elevation sectional view of a second type future generation input screen utilizing my barrier layer.

Referring now in particular to FIG. 1, there is shown a conventional x-ray image intensifier tube comprised of a glass envelope 10 having an input window 10*a* through which the x-ray photons pass after having traversed through a patient's body. A conventional type input screen comprising a substantially uniform phosphor layer 11 on which is deposited a thin photocathode film 12 may be formed on the inner surface of input window 10*a* or, alternatively, as illustrated in FIG. 1, the phosphor layer 11 is formed on a separate substrate member or face plate 13 which is slightly spaced from the inner surface of input window 10*a* in the order of ½ inch. Face plate 13 is supported within glass envelope 10 and oriented parallel to the input window 10*a*. The photoemitting film 12 forms the cathode of the x-ray image intensifier tube and is electrically connected to the negative polarity terminal of a power supply which energizes the tube. The phosphor may be of the granular type such as zinc cadmium sulfide or of the transparent type such as cesium iodide as typical materials and the thickness of the layer (or multi-layers) is generally in the range of 5 to 15 mils. The photocathode film 12 has a thickness typically in the range of 50 to 250 Angstroms. The photoemitting material in film 12 is typically of the multi-alkali type and has a relatively low electrical sheet conductance thereby presenting a relatively high electrical resistance.

An electrically conductive ring 14 having its inner surface in contact with the outer edges of the photocathode film 12 (or an electrically conductive strip in contact with the edges of film 12) is utilized for applying the negative potential symmetrically to such film. The ring electrode 14 may also serve to support the input screen assembly (11, 12, 13) in its proper orientation within glass envelope 10. In the case of the input screen being formed directly on the input window 10*a*, a film of electrically conductive material such as evaporated aluminum may be deposited on the inner surface of the glass envelope along the edge of the input screen and in contact with the photocathode film for applying the potential thereto. Alternatively, and in both cases of the input screen being formed directly on input window 10*a* or on a separate substrate member 13, the inner major surface of window 10*a* or member 13 may be completely coated with the evaporated aluminum to form a light-reflective surface to any rearward traveling light photons in the phosphor layer and thereby increase the number of light photons directed to the photocathode film 12. Obviously, in the case of a separate substrate member 13 as shown in FIG. 1, it may be fabricated of glass or a low atomic number metal such as aluminum, in the latter case the evaporated aluminum coating not being required. In any case, the (photo) cathode electrode 12 is electrically connected to the negative polarity terminal of the power supply by means of a suitable electrical conductor 15 passing through the wall of glass envelope 10 via a vacuum seal.

The photoelectrons emitted from photocathode film 12 are focussed by electrode 16 which is maintained at a potential of several hundred volts positive with respect to photocathode film 12 and are accelerated to approximately 25 kilovolts as one typical example by means of anode electrode 17 positioned within the output end of glass envelope 10. Focussing electrode 16 is generally oriented either along the inner surface of glass envelope 10 in the region between the cathode and anode electrodes, or may be slightly spaced therefrom. Electrodes 16 and 17 are suitably shaped to provide the desired electron-optical focussing of the accelerated photoelectrons onto the output phosphor screen 18 which is formed either on the inner end 10*b* surface of glass envelope 10 or slightly spaced therefrom. The image appearing on the second phosphor screen 18 is a much brighter version of the image on the input phosphor screen 11 and can be viewed directly by the physician or be subjected to further processing. The paths of two photoelectrons between the photocathode film 12 and output phosphor screen 18 are indicated by dashed line and arrowheads.

The thickness of the phosphor layer in conventional image intensifiers is a compromise between a thick layer necessary for high x-ray absorption and a thin layer necessary for high image resolution and local image contrast. As a result, the conventional 5 to 15 mil thickness phosphor layer has a relatively low x-ray absorption in the order of 15 to 35 percent of the incident x-rays and future generation input phosphor screens to be described hereinafter with reference to FIGS. 9 and 10 can result in thicker phosphor layers to thereby increase the x-ray absorption, and thus the sensitivity, but with less loss in resolution and local contrast than occurs in conventional image intensifiers, or alternatively, will utilize conventional thickness phosphor layers but obtain increased resolution and contrast.

FIG. 2 illustrates a second embodiment of a conventional input screen of an x-ray image intensifier wherein the major surface of the support member 13 adjacent the source of x-ray photons is the support for phosphor layer 11, and the opposite major surface of the support member 13 is the support for photocathode film 12. In view of the orientation of phosphor layer 11 and photocathode film 12 relative to support member 13, member 13 must be fabricated of a phosphor luminescence transparent material such as glass and is typically of 5 mils thickness. The phosphor layer 11 is illustrated as consisting of a relatively thick multi-layer of relatively large size phosphor grains (i.e., of particle diameter greater than 0.3 mil in order to have high light transmission characteristics). Although the phosphor grains are illustrated for convenience as being spherical, it is to be understood that the grains generally are not quite spherical in shape. Also, the grains are not necessarily equal in size due to the process of formation of such granular phosphor. The granular phosphors in the FIG. 2 embodiment are very thinly coated with a silicone resin such that upon compaction of the phosphors the resin provides an adhesive effect for retaining the phosphors on the surface of substrate member 13. The granular phosphors 11 may be zinc cadmium sulfide or gadolinium oxysulfide as two suitable granular phosphors. In some cases, a suitable activator is added to the phosphor host material, typical activators for zinc cadmium sulfide being silver and for gadolinium oxysulfide being terbium. The photoemitter material forming photocathode film **12** may be of the common types known as S-20 (a compound of antimony, cesium, sodium and potassium) or S-11 (a compound of cesium, antimony and oxygen) as two typical examples, and is of thickness in the hereinabove recited range of 50 to 250 Angstroms, and typically may be 150 Angstroms.

The FIG. **2** input screen has an advantage over the input screen depicted in FIG. **1**, and in greater detail in FIG. **3**, in that the photocathode film **12** is deposited upon a smooth surface of the glass support member **13** thereby eliminating electron-optical image distortion due to a nonuniformly thick or nonuniformly resistive photocathode film resulting from irregularities along the output surface of the phosphor layer. However, since only the edges of the photocathode film **12** in the FIG. **2** embodiment are in contact with the electrically conductive ring member **14** for applying the proper potential to the photocathode (as in the case of FIG. **1**), the electron-optic image distortion due to variation of electric potential laterally across the photocathode film remains as a source of electron-optic image distortion in this conventional input screen structure.

FIG. **3** is an enlarged view of a portion of the input screen depicted in FIG. **1**. In addition to the distinction between the FIGS. **2** and **3** embodiments in the relative orientation of the substrate member **13**, the substrate member **13** in FIG. **3** may be fabricated of glass, aluminum or other low atomic number metal whereas substrate member **13** in FIG. **2** is restricted to a phosphor luminescence optically transparent material such as glass. The phosphor layer **11** in FIG. **3** consists of a granular phosphor which may be of the same type and size as in FIG. **2**, but is embedded in a silicone resin, that is, the resin occupies a substantial part of the volume in the phosphor layer in order of 15 to 30 percent whereas any resin employed in the FIG. **2** embodiment is merely for causing adherence of the phosphor grains to each other and to the substrate member. One of the main reasons for using granular phosphor in a silicone resin binder is to eliminate the several mils separation between phosphor and photocathode represented by the thin glass substrate in FIG. **2**, which separation causes a degradation of local image contrast and resolution (i.e., a degradation of the image modulation transfer function), and it should be understood that the granular phosphors in the FIG. **2** embodiment can also be in a resin binder.

As stated hereinabove, a thin barrier layer **30** of an electrically insulating, phosphor luminescence transparent material has conventionally been utilized as an interface between the phosphor layer and photocathode film to obtain chemical isolation therebetween. The barrier layer **30** has a thickness typically in the range of 0.1 to 1.0 micron and is fabricated of materials such as aluminum oxide or silicone dioxide. The thinness of this barrier layer is sufficient to obtain the desired chemical isolation between the phosphor and photoemitter materials, but such thinness results in only a slight smoothing of irregularities on the phosphor surface. This conventional barrier layer **30** is not used in the FIG. **2** input screen since there is no interface between the phosphor layer **11** and the photocathode film **12**.

Referring now to FIG. **4**, there is shown a relatively new type of input screen which utilizes evaporated transparent phosphor material rather than the granular type utilized in the FIGS. **2** and **3** embodiments. The transparent phosphor material may be thallium activated cesium iodide as one typical example, is of thickness in the same range as the layers in FIGS. **2** and **3** (5 to 15 mils) and has the advantage over the granular phosphors in that it has a higher light transmission characteristic and theoretically sould have no surface irregularities thereby permitting a more uniform photocathode film **12** to be deposited thereon. However, in practice, a difficulty arises in depositing evaporated phosphor in that there invariably develops a grain growth or general cracking due to thermal stress thereby developing an undesired physical network of phosphor islands formed by cracks which progress from the free surface of the evaporated phosphor **11** toward the aluminum or glass substrate **13** and may even develop completely to such substrate surface. The electrically nonconductive thin barrier layer **30** may be utilized as a chemical isolating interface between the evaporated phosphor material **11** and photocathode film **12**, and additionally may result in some smoothing or the unintentionally structured phosphor layer by bridging across, hopefully, at least some of the cracks developed from the free surface of the evaporated phosphor. Thus, the use of electrical insulating barrier layer **30** in the FIG. **4** prior art embodiment may also result in some reduction in the electronoptic image distortion arising from a nonuniform thickness or nonuniformly resistive photocathode film deposited on an irregular surface on the phosphor layer, and more specifically in the case of the FIG. **4** embodiment, arising from microscopic and macroscopic electrical island formation on the phosphor surface due to the cracks developed from the free surface thereof. However, as in the case of the FIG. **3** embodiment, conventional electrically insulating, thin barrier layer **30** has no effect on the electron-optic image distortion arising from the uniform drop in potential laterally across the photocathode film due to the high electrical resistance thereof.

In accordance with my invention, I provide a barrier layer as a chemically isolating interface between the phosphor layer and photocathode film which is formed of a material completely different from the materals utilized in the above-described prior art barrier layers to thereby obtain a significantly improved x-ray image intensifier input screen. In particular, I utilize a material which has the desirable characteristics of the prior art barrier layer materials, namely, low vapor pressure such that it can be deposited at low pressure by a simple process and at low cost, phosphor luminescence transparency for good optical coupling and image conversion and chemical compatibility with the phosphor and photoemitter materials both during fabrication and throughout the lifetime of the image intensifier. But most importantly, and the prime distinguishing features between my barrier layer material and the prior art, I utilize a material which is relatively electrically conductive, and the layer is of substantial thickness. The electrically conductive characteristic of my barrier layer material is defined as a material having an electrical resistance in the range of 10 to 10^6 ohms per square, and is typically 1,000, to provide sufficient electrical sheet conductance relative to the photocathode film whereby the resistance of my barrier layer is significantly less than the resistance of the photocathode film.

As a result, my barrier layer which is electrically connected to the negative polarity terminal of the power supply, effectively electrically short-circuits the photocathode film and thereby provides electron replenishment to the photocathode film at all points of electron emission therefrom. This electron replenishment substantially reduces the potential drops developed laterally across the photocathode film and thereby results in a significant reduction in electron-optic image distortion due to such factor which cannot be obtained with the conventional type conductive barrier layer. My barrier layer is also sufficiently thick (0.1 to 25 microns) to afford substantial smoothing or bridging of surface irregularities on the phosphor layer and thereby also obtain a significant reduction in electron-optic image distortion due to such factor.

In accordance with my invention I have found that indium oxide (In_2O_3) is a first material which is especially suitable for forming my electrically conductive barrier layer. It can be applied in either of two ways: it can be evaporated onto a room temperature substrate at low oxygen pressure (e.g., 10 microns for example) and subsequently fully oxidized in air at 200°C and 1 atmosphere for times from 30 minutes to 2 hours; or, it may be applied in a one step bell jar process by evaporating indium onto a 200° to 300°C substrate in the presence of 50 – 150 microns oxygen, no further oxidation being necessary. FIG. **5** illustrates the wavelength responses of the indium oxide and two materials for which it functions as the barrier layer, namely, a thallium-activated cesium iodide phosphor and the S-**20** type photoemitter material. The response curve designated "PHOSPHOR CsI:T*l*" is a plot of the relative spectral emission of the activated cesium iodide vs. wavelength in Angstroms. THe curve designated "PHOTOCATHODE S-20 " is the relative photocathode response for the photocathode material S-20, a compound of an antimony, cesium, sodium and potassium. Finally, curve "BARRIER LAYER In_2O_3" is a plot of (1-*a*) where "*a*" is the absorbtivity of indium oxide In_2O_3. A comparison of the three curves indicates that the response of indium oxide is very well matched to that of the cesium iodide phosphor and S-20 photocathode in that its peak transmission is over a sufficiently broad wavelength band to include the significant wavelength responses of cesium iodide phosphor and S-20 photocathode materials. In fact, the broad spectral transmission of the indium oxide makes it suitable for use with virtually any of the x-ray sensitive phosphors which have spectral emission in the visible band of wavelengths and with other newer negative electron affinity photocathodes such as gallium arsenide GaAs:Cs. My invention is therefore basically the use of indium oxide, or other suitable electrically conductive, x-ray luminescence optically transparent materials to be described hereinafter as a barrier layer between the phosphor layer and photocathode film of an x-ray image intensifier tube. The use of this new and improved barrier layer is not limited to the conventional type x-ray image intensifier input screens but is also equally important for use with future generation type input screens to be described hereinafter.

Referring now to FIG. **6**, there is shown a first embodiment of the use of my electrically conductive barrier layer in an X-ray image intensifier input screen. The input screen in the FIG. **6** embodiment corresponds to the conventional input screen illustrated in FIG. **2** wherein the phosphor layer **11** and photocathode film **12** are disposed on opposite sides of a smooth glass (or other phosphor luminescence transparent material) substrate member **13.** Due to the glass substrate **13** presenting a smooth surface to the photocathode film, the electon-optic image distortion is due primarily to the symmetrical changes in potential developed laterally across the (high resistance) photocathode film from the ring electrode to the center of the film as described hereinabove. My electrically conductive, x-ray phosphor luminescence optically transparent barrier layer **60**, which may be indium oxide as one example, is deposited on the surface of the glass substrate member **13** such that it is disposed between the glass substrate and the photocathode film **12** as illustrated in FIG. **6.** Barrier layer **60** is of substantially uniform thickness such that photocathode film **12** also retains its smooth surface as it had in the FIG. **2** conventional embodiment. The various thicknesses of elements **11**, **12** and **13** in the FIG. **6** (and also FIGS. **7–10**) embodiments may be the same as in the FIGS. **2** (and **3** and **4**) embodiments. Barrier layer **60** in all of the embodiments herein described is of thickness in the range between 0.1 to 25 microns, and in the FIG. **6** embodiment would generally be in the lower portion of the thickness range since it does not have to provide the smoothing of surface irregularities function in the phosphor layer as in the embodiments to be described hereinafter. Thus, the barrier layer thickness in the FIG. **6** embodiment is more generally in the range between 0.1 to 1.0 microns. Barrier layer **60** is deposited on glass substrate member **13** in a pattern such that the edges of layer **60** slightly overlap the side surfaces of substrate **13** and therefore come in contact with ring electrode **14** (see FIG. **1**). Alternatively, an aluminum or other highly electrically conductive film may be formed along the edges of barrier layer **60** to provide electrical connection thereof to the ring electrode. Since barrier layer **60** is connected to the source of potential (via conductor **15** shown in FIG. **1**) there is no need for photocathode film **12** to be also so connected, and my barrier layer **60** provides electron replenishment to the photocathode film at all points of electron emission therefrom to thereby significantly reduce electron-optic image distortion due to undesired relatively high potential drops developed laterally across the photocathode film.

Upon barrier layer **60** having been deposited on substrate **13**, the photocathode film **12**, which may be of the multi-alkaline types hereinabove-described, is deposited on barrier layer **60** by conventional techniques.

Referring now to FIG. **7**, there is shown a second embodiment of an input screen utilizing my barrier layer, and in particular is an improvement over the conventional input screen illustrated in FIG. **3.** Thus, in FIG. **7**, my barrier layer **60** is deposited directly on the irregular surface of phosphor layer **11.** Alternatively, an electrically nonconductive barrier layer **30**, as defined with reference to FIG. **3**, may be deposited on the irregular surface of the phosphor layer **11** for additional chemical compatibility of the phosphor and photocathode materials, and my electrically conductive barrier layer **60** is then deposited on top of barrier layer **30** such that the electrically conductive barrier layer **60** is in contact with the photocathode film **12.** Thus, if desired, both type barrier layers can be utilized in the input screen with the electrically conductive barrier layer being in contact with the photocathode film and connected to the source of potential in order to provide electron replenishment thereto. In the FIG. 7 embodiment, and assuming that the nonconductive barrier layer is not utilized, my electrically conductive barrier layer **60** provides the advantages described with reference to the use of such barrier layer in the FIG. 6 embodiment as well as providing chemical isolation between phosphor (or phosphor-in-resin) layer **11** and photocathode film **12**, being compatible with both materials during preparation and throughout the life thereof and affording substantial smoothing or bridging of surface irregularities in the phosphor layer **11** such that electron-optic image distortion from this second factor is also substantially reduced in addition to the reduction in such distortion due to uniform drops in potential laterally across the photocathode film. The electrically conductive barrier layer **60** thickness in my FIG. 7 embodiment is generally in the mid portion of the 0.1 to 25 micron range and therefore is more generally of thickness in the range of 0.5 to 3 microns, especially in the case wherein nonconductive barrier layer **30** is not employed.

Referring now to FIG. **8**, there is shown my improved version of the input screen depicted in FIG. 4 wherein phosphor layer **11** is an evaporated transparent phosphor such as cesium iodide. The network of microscopic and macroscopic electrical islands formed by the cracks progressing from the free surface of the evaporated phosphor layer **11** which progress toward or actually to the aluminum (or other low atomic number metal) or glass substrate member **13** are substantially eliminated by depositing my electrically conductive barrier layer **60** (of thickness in the range of 1 to 3 microns) along the entire free surface of evaporated phosphor layer such that surface continuity exists over the phosphor surface and the physical network of islands is no longer present and the edges of layer **60** are connected to the source of potential. However, barrier layer **60** bridges the cracks developed from the surface of the phosphor layer and also penetrates into the voids developed by such cracks, and in the case of the cracks extending to (i.e., contacting) the surface of an aluminum substrate which has its side surfaces connected to the ring electrode, it may not be necessary to provide an electrical connection from the outer edges of barrier layer **60** to the ring electrode. Alternatively, and especially in the case wherein substrate member **13** is formed of electrically insulating material such as glass, the conventional electrical insulating barrier layer **30** may be deposited on the cracked surface of the evaporated phosphor layer **11** and my electrically conductive barrier layer **60** then deposited on top of the insulating layer. In this latter embodiment, the electrically conductive barrier layer **60** obviously must be electrically connected to the ring electrode.

Referring now to FIG. **9**, there is shown what may be described as a future generation input screen wherein the phosphor layer is an intentionally fabricated array of columnar, honeycomb, or other generally symmetrically arranged phosphor structures which provide a light piping effect to the phosphor luminescence. The phosphor layer is thus a single layer of a plurality of spaced apart relatively thick phosphor structures **11** having base portions disposed along and in adherence with a low atomic number metal substrate member **13** on the major surface thereof that is opposite from the source of the x-ray photons. The columnar phosphor structures **11** illustrated in FIG. **9** may be generally square, hexagonal or even circular in cross section as typical shapes and have a height (distance normal from substrate member **13**)-to-width ratio in the range of 2:1 to 10:1. Although the phosphor structures **11** are preferably equally spaced apart and are of identical dimension, this may not occur in a practical sense due to possible difficulties in the fabrication process thereof. Thus, as illustrated in FIG. **9** the columnar structures **11** are not equally spaced apart and the shapes, although similar, are not identical. The light piping effect produced by the intentionally structured phosphor layer provides a high resolution-high contrast input phosphor screen and cesium iodide is a typical transparent phosphor which is especially suitable for this embodiment. My electrically conductive barrier layer material, such as indium oxide, is deposited along the entire nonbase portion of the phosphor structures by evaporation as in the previous embodiments such that for the more narrowly spaced apart phosphor structures, the electrically conductive barrier layer material **60** completely fills the voids therebetween, whereas in the more widely spaced apart structures, the barrier layer material coats such nonbase surfaces of the phosphor structures but a much smaller void may remain between such structures. Thus, in the case of the narrowly spaced apart phosphor structures **11**, my conductive barrier layer **60** bridges the adjacent phosphors along the free ends thereof whereas the more widely spaced apart phosphor structures do not have their free ends bridged. The photocathode film **12** is then evaporated only upon the surfaces of the barrier layer formed along the free ends of the phosphor structures such that photocathode film is continuous in the regions wherein the barrier layer bridges adjacent phosphor structures, and is discontinuous wherein such bridging does not occur. In either event, since the conductive barrier layer material **60** extends from the base of the phosphor structures **11** to the photocathode film, such barrier layer provides electron replenishment to each portion of the photocathode film **12.** In the event substrate member **13** is fabricated of glass of other x-ray transparent, electrically insulating material, the major surface of substrate member **13** along which the base portions of the phosphor structures **11** are disposed is first coated with an electrically conductive film such as evaporated aluminum and this film, or the electrically conductive substrate member, if used, are electrically connected to the ring electrode. The thickness of layer **60** would typically be in the range of 1 to 3 microns.

FIG. **10** illustrates a second embodiment of a future generation input screen wherein granular phosphors are utilized with no, or very limited amount of binder material and the electrically conductive barrier layer material **60** is intended to cover major portion of the outer surface presented by the multi-layers **11** of phosphor grains. In this embodiment, the evaporation of the electrically conductive barrier layer material at the low pressure of several tens of microns causes such conductive layer to extend over all of the exposed surfaces of the phosphor grains in a thickness range of 2 to 25 microns as well as behind the grains in the regions where the grains are adjacent to or in contact with substrate member **13.** The barrier layer does not necessarily have to fill the larger voids between adjacent more widely spaced apart phosphor grains as is depicted in FIG. **10.**

Indium oxide adheres very well to the thick phosphor film of the structured phosphor layer in FIG. **9,** as illustrated in FIG. **8** as well as to the phosphor grains depicted in FIGS. **7** and **10.** Other suitable electrically conductive barrier layer materials which may be used in any of the embodiments hereinabove described are slightly chemically reduced titantium diode TiO_2, cuprous iodide CuI, and zinc oxide ZnO.

From the foregoing description, it can be appreciated that may invention makes available an x-ray image intensifier tube having a new and improved input screen which, due to the use of an electrically conductive barrier layer between the phosphor material and photocathode material significantly reduces electron-optic image distortion due to undesired unifrom potential drops and nonuniform potential variations laterally across the photocathode film by providing electron replenishment to the photocathode film as well as smoothing surface irregularities on the phosphor layer. The electrically conductive barrier layer provides a compatible interface between the phosphor layer and photocathode for both conventional type input screens and future generation high resolution-high contrast input screens.

Having described a number of specific embodiments of my input screen, it is believed obvious that modification and variation of my invention is possible in light of the above teaching. Thus, other materials suitable for my electrically conductive barrier layer other than those enumerated above may also be used as long as they meet the limitations of having an electrical resistance in the range of 10 to 10^6 ohms per square and are optically transparent to the particular phosphor luminescence involved, provide chemical isolation between the phosphor and photocathode materials and are compatible therewith and can be deposited in sufficient thickness to provide a smoothing or bridging of surface irregularities or cracks in the phosphor layer. Finally, there may be some applications wherein a very thin (approximately 10 Angstroms) film of an electrically insulating material may be utilized between the electrically conductive barrier layer and photocathode film, but in this latter case the insulating or nucleating film would be sufficiently thin such that its desired characteristics would be effective without providing substantial electrical insulation between the electrically conductive barrier layer and photocathode film. It is, therefore to be understood that changes may be made in the particular embodiment described which are within the full intended scope of the invention as defined by the following claims.

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

1. An improved x-ray image intensifier tube input screen comprising

a substrate member for supporting an x-ray sensitive phosphor layer thereon,

an x-ray sensitive phosphor layer having a first major surface disposed along a major surface of said substrate member opposite from a source of x-ray photons, the phosphor layer being a multilayer of granular phosphors of relatively large grain size of particle diameter greater than 0.3 mil embedded in a silicone resin binder, and

a photocathode film in optical communication with said phosphor layer for producing emission of photoelectrons therefrom in response to x-ray photons being converted to light photons by luminescence in said phosphor layer,

the improvement consisting of

a relatively thick barrier layer of a relatively electrically conductive material, optically transparent to the phosphor luminescence, chemically compatible with the photocathode film material and with the phosphor and providing chemical isolation between the phosphor layer and photocathode film, said barrier layer having a first major surface disposed along a second major surface of said phosphor layer opposite the first major surface thereof, said photocathode film disposed along a second major surface of said barrier layer opposite the first major surface thereof, the thickness of said barrier layer being in the range of 0.5 to 3 microns so that it is sufficient to provide substantial smoothing of surface irregularities on the second major surface of the phosphor layer and permitting a more uniform thickness of said photocathode film to be deposited thereby reducing electron-optic image distortion due to nonuniform potential variations across said photocathode film resulting from the nonuniform thickness of nonuniform resistance thereof, the barrier layer material having an electrical resistance in the range of 10 to 10^6 ohms per square to provide sufficient electrical sheet conductance relative to said photocathode film so that said barrier layer upon being connected to a source of electric potential provides electron replenishment to said photocathode film to thereby significantly reduce electron-optic image distortion due to undesired relatively high potential drops across said photocathode film laterally thereof, and

a barrier layer of a relatively electrically nonconductive material disposed between said electrically conductive barrier layer and said phosphor layer.

2. The improved input screen set forth in claim **1** wherein

said nonconductive barrier layer is of thickness in the range of 0.1 to 1.0 micron.

3. The improved input screen set forth in claim **1** wherein

said relatively electrically nonconductive material is aluminum oxide.

4. An improved x-ray image intensifier tube input screen comprising

a substrate member for supporting an x-ray sensitive phosphor layer thereon,

an x-ray sensitive phosphor layer disposed along a major surface of said substrate member, and

a photocathode film in optical communication with said phosphor layer for producing emission of photoelectrons therefrom in response to x-ray photons being converted to light photons by luminescence in said phosphor layer,

the improvement consisting of

said phosphor layer being a single layer of a plurality of slightly spaced apart relatively thick phosphor structures providing a light piping effect to the phosphor luminescence and having base portions disposed on said substrate member along a major surface thereof opposite from a source of the x-ray photons, and

a relatively thick barrier layer of a relatively electrically conductive material, optically transparent to the phosphor luminescence, chemically compatible with at least the photocathode film material, and disposed between said phosphor layer and said photocathode film, the thickness of said barrier layer being sufficient to provide substantial smoothing of surface irregularities on the phosphor layer, the barrier layer material having an electrical resistance in the range of 10 to 10^6 ohms per square to provide sufficient electrical sheet conductance relative to said photocathode film so that said barrier layer upon being connected to a source of electric potential provides electron replenishment to said photocathode film to thereby significantly reduce elctron-optic image distortion due to undesired relatively high potential drops across said photocathode film laterally thereof.

5. The improved input screen set forth in claim **4** wherein

said barrier layer deposited along the nonbase portions of the phosphor structures to thereby coat at least the surface portion of the phosphor structures opposite the base portion thereof, and

said photocathode film disposed along the barrier layer deposited on the surface portions of the phosphor structures opposite the base portions thereof.

6. The improved screen set forth in claim **5** wherein

said relatively thick phosphor structures are of columnar shape and the axes thereof are substantially normal to said substrate member,

said barrier layer being of thickness in the range of 1 to 3 microns.

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