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X-RAY IMAGE INTENSIFIER TUBE HAVING A NON-SPECULAR BACKING FOR THE SCINTILLATOR LAYER

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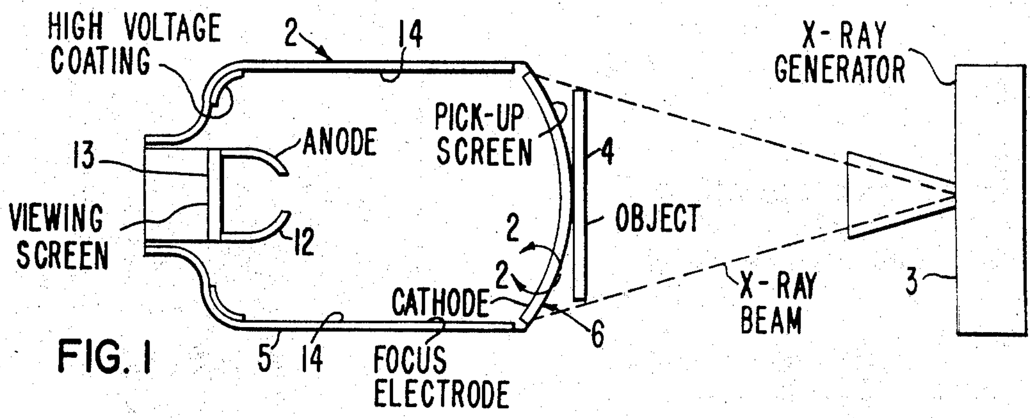
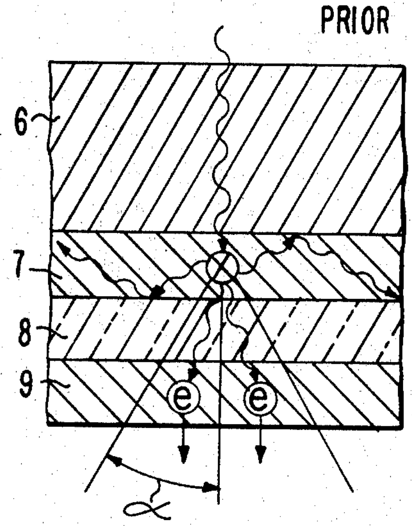


FIG. 1

FIG. 2
PRIOR ART



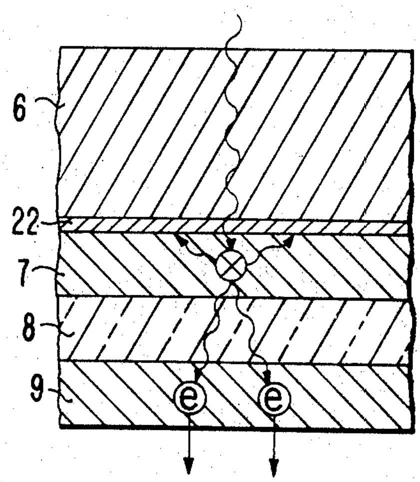


FIG. 4

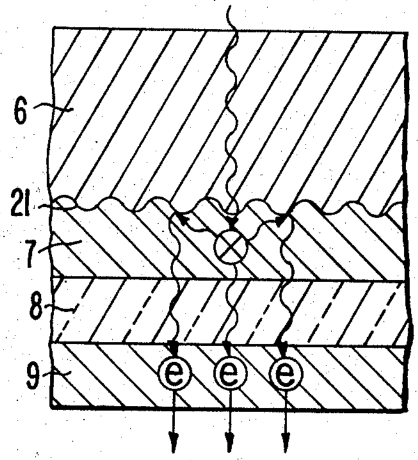


FIG. 3

INVENTORS
CLAYTON W. BATES, JR.
RONALD L. BELL

BY [signature]

ATTORNEY

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X-RAY IMAGE INTENSIFIER TUBE HAVING A NON-SPECULAR BACKING FOR THE SCINTILLATOR LAYER

Clayton W. Bates, Jr., San Francisco, and Ronald L. Bell, Woodside, Calif., assignors to Varian Associates, Palo Alto, Calif., a corporation of California

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U.S. Cl. 313—101 4 Claims

ABSTRACT OF THE DISCLOSURE

In the improvement of the present invention a non-specular surface is provided between the scintillator layer and its mechanical supportive structure, which may be the X-ray transmissive portion of the envelope for producing improved performance of the X-ray image intensifier tube. In one embodiment, the non-specular surface is formed by roughening the surface of the supportive structure which faces the scintillator such that the surface has a characteristic roughness greater than the wavelength of the optical photons emitted by the scintillator such that the photons are not trapped in the scintillating layer but are reflected from the roughened surface back through the scintillator material to the photo cathode to improve the conversion efficiency of the image intensifier tube. In another embodiment, the non-specular backing surface is provided by a light absorptive layer disposed between the scintillator and the supportive structure for absorbing photons back-scattered from the scintillator. In this manner, the definition of the X-ray image intensifier tube is substantially improved because the back-scattered photons are not reflected back to the photo cathode emitter tube to form an image which would be more diffused than the image obtained from the optical photons which are forward scattered. The roughened face of the supporting layer is conveniently made by forming this part of aluminum and anodizing its surface to form the non-specular surface. The anodized coating is preferably white to provide a relatively high albedo. The light absorptive layer, as employed for improved definition may, for example, be formed by a layer of carbon.

DESCRIPTION OF THE PRIOR ART

Heretofore, it has been proposed to vapor deposit an activated alkali metal halide scintillator layer directly upon an aluminum supporting structure of an X-ray intensifier tube. Such an X-ray intensifier tube is described and claimed in copending U.S. application 606,514 filed Dec. 27, 1966, Pat. No. 3,402,792 and assigned to the same assignee as the present invention. Such an X-ray pickup screen has improved stopping probability for X-rays as compared with prior X-ray pickup screens which have employed particulated scintillating material such as, for example, zinc sulphide. The improved stopping probability for X-rays and thus, conversion efficiency, arises due to the improved absorptive powers of the alkali metal halides such as cesium iodide and due to the fact that the vapor-deposited layer has a higher density than obtainable by a settled layer of particulated zinc sulphide material. However, in this prior device the scintillator layer was deposited directly upon a clean and polished substrate member forming the X-ray window of the pickup tube. In such a case it is found that a substantial proportion of the emitted optical photons, generated in the scintillator layer, tend to be trapped in the scintillator layer due to internal reflection and, thus, these trapped photons do not pass into the photo-emitting layer to contribute to the electron image. Thus, the intensifier tube has less than optimum

conversion efficiency. Also, it is found that the photons that are back-scattered from the scintillator layer may be reflected from the substrate back through the scintillator layer to the photo-emitting layer tending to diffuse the converted X-ray image. Therefore, it is desired to provide means for inhibiting the light-trapping effect in the scintillator for X-ray image-intensifier tubes where high conversion efficiencies are desired and it is desired to absorb the back-scattered optical photons in X-ray image intensifier tubes where high definition is desired.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved X-ray image intensifier tube.

One feature of the present invention is the provision, in an X-ray image intensifier tube, of providing a non-specular surface between the X-ray transmissive supporting member and the scintillator layer for improving the performance of the X-ray image intensifier tube.

Another feature of the present invention is the same as the preceding feature wherein the non-specular surface comprises a roughened surface having a characteristic surface roughness greater than the wavelength of the optical photons emitted in the scintillator layer, whereby trapping of optical photons in the scintillator layer is inhibited to improve the conversion efficiency of the image intensifier tube.

Another feature of the present invention is the same as the preceding feature wherein the non-specular surface is provided by an anodized aluminum surface having a relatively high albedo, whereby the conversion efficiency of the tube is substantially improved.

Another feature of the present invention is the same as the first feature wherein the non-specular surface is provided by a layer of light-absorptive material, whereby the definition of the converted X-ray image is substantially improved.

Another feature of the present invention is the same as the preceding feature wherein the layer of light-absorptive material may, for example, be formed by carbon.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic line diagram of an X-ray image intensifier tube,

FIG. 2 is an enlarged cross-sectional view of a portion of the structure of FIG. 1 delineated by line 2—2 and depicting the prior art,

FIG. 3 is a view similar to that of FIG. 2 depicting a pickup screen construction of the present invention, and

FIG. 4 is a view similar to that of FIG. 3 depicting an alternative construction of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown an X-ray system employing an X-ray image intensifier tube **2**. Such a system is described in an article entitled, "X-ray Image Intensification With a Large Diameter Image Intensifier Tube," appearing in the American Jnl. of Roentgenology Radium Therapy and Nuclear Medicine, vol. 85, pp. 323–341 of February 1961. Briefly, an X-ray generator **3** serves to produce and direct the beam of X-rays onto an object **4** to be X-rayed. The image intensifier tube **2** is disposed to receive the X-ray image of the object **4**.

The image intensifier tube **2** includes a dielectric vacuum envelope **5**, as of glass, approximately 17 inches long and 10 inches in diameter. The pickup face portion **6** of the tube **2** comprises a spherical X-ray transparent portion of the envelope 5, as of aluminum or conductive glass, which is operated at cathode potential. An image pickup screen 7 (see FIG. 2), made of an X-ray sensitive scintillator such as an activated alkali metal halide, is deposited onto the inside spherical surface of the envelope portion 6 to a thickness as of 0.01″. A chemically inert optically transparent buffer 8 is coated over the scintillator layer 7. A photo cathode layer 9 is formed over the buffer layer 8.

In operation, the X-rays penetrate the object 4 to be observed. The local X-ray attenuation depends on both the thickness and atomic number of the elements forming the object under observation. Thus, the intensity pattern in the X-ray beam after penetration of the object 4 contains information concerning the structure of the object. The X-ray image passes through the envelope section 6 and falls upon the X-ray sensitive scintillator layer 7 wherein the X-ray photons are absorbed and re-emitted as optical photons. The optical photons pass through the transparent buffer 8 to the photo cathode 9 wherein they produce electrons. The electrons are emitted from the photo cathode in a pattern or image corresponding to the original X-ray image. The electrons are accelerated to a high velocity, as of 30 kv., within the tube 2 and are focused through an anode structure 12 onto a fluorescent screen 13 for viewing by the eye or other suitable optical pickup device. Electron focusing electrodes 14 are deposited on the interior surfaces of the tube to focus the electrons through the anode 12.

In the intensifier tube 2, one 50 kev. of X-ray energy absorbed by the X-ray sensitive scintillator screen 7 produces in the case of Na doped CsI about 2,000 photons of blue light. These two thousand photons of blue light produce about 400 electrons when absorbed in the photo cathode layer 9. The 400 electrons emitted from the photo cathode produce about 400,000 photons of light in the visible band when absorbed by the fluorescent viewing screen 13. Thus, the X-ray image is converted to the visible range and greatly intensified for viewing.

Referring now to FIG. 2 there is shown a prior art X-ray pickup screen in greater detail. In operation, an X-ray or gamma ray passes through the X-ray transmissive envelope face 6 and is absorbed in the scintillator layer 7 giving rise to emission of optical photons. Some of the emitted photons travel in the direction of the original X-ray or gamma ray. Other optical photons are emitted or are back scattered toward the face 6 of the X-ray image intensifier tube 2. It turns out that for relatively dense scintillator layers of alkali metal halide material such as, for example, cesium iodide, that optical photons which are not within a relatively small cone, indicated by the solid angle α, will be trapped in the scintillator layer 7 by being reflected from the surfaces of the scintillator 7 due to the difference in dielectric constant of the scintillator 7 and the dielectric constant of the layers 6 and 8 on opposite sides of the scintillator 7. The angle α is referred to as the angle of internal reflection and for cesium iodide with a Cs_3Sb photocathode overlay this angle is approximately 62°. Thus, a relatively large percentage of the photons emitted by the scintillator 7 are trapped in the scintillator layer 7 and do not contribute to the photon image to be picked up by the photo cathode layer 9 to produce the electron image. This tends to detract from the conversion efficiency of the image intensifier 2.

Referring now to FIG. 3 there is shown an X-ray pickup screen construction embodying features of the present invention. More specifically, the surface of the X-ray transmissive window 6 of the image intensifier tube 2 which faces the scintillator layer 7 is roughened to a characteristic surface roughness greater than the wavelength of the optical photons emitted in the scintillator layer 7. This roughened surface is indicated at 21. The roughened surface 21 forms a non-specular backing for the scintillator layer 7 causing the photons which are back-scattered to surface 21 to be reflected at angles having a higher probability of falling within the solid angle α, such that a relatively high percentage of the photons which are emitted from the scintillator layer 7 will pass out of the layer 7 to the photo cathode 9 where they can contribute to the electron image. Thus, the conversion efficiency of the structure of FIG. 3 is substantially improved as compared with the prior art structure, wherein the surface of the substrate member 6 which faces the scintillator layer 7 provides a specular, i.e. mirror-like reflection of optical photons incident thereon.

The roughened surface 21, as previously mentioned, has a characteristic surface roughness greater than the wavelength of the optical photons emitted by the scintillator layer 7. This means that the surface roughness will generally be at least on the order of 1 micron and should, of course, be less than the thickness of the scintillator layer 7. Suitable alkali metal halide scintillator materials forming the scintillator layer 7 include activated, cesium iodide, potassium iodide, sodium iodide, rubidium iodide, cesium bromide, and lithium iodide.

In one preferred embodiment of the present invention, the X-ray window 6 is formed by a sheet of aluminum and the roughened surface 21 is provided by anodizing the surface of the aluminum substrate member 6. Such an anodized surface will be white and will have a high albedo further improving the conversion efficiency of the X-ray image intensifier tube. In case the pickup face 6 is made of a conductive glass, the glass may be roughened as by etching the surface facing the scintillator layer 7. Its reflectivity may also be improved by coating the face with a flash coating of aluminum and then anodizing the aluminum to produce a white, rough surface having the high albedo.

Referring now to FIG. 4 there is shown an alternative X-ray pickup screen embodiment of the present invention. This screen construction is substantially the same as that of FIG. 2 except that a light absorptive layer 22 is provided between the scintillator layer 7 and the inside surface of the X-ray transmissive window 6. X-rays or gamma rays passing through the window 6 are absorbed in the scintillator layer 7 to produce optical photons which are emitted from the scintillator layer 7. Some of these photons are emitted within the angle α and pass out of the scintillator 7 through the buffer to the photo cathode layer 8 wherein they are absorbed and cause emission of electrons to form the electron image. Those photons which are back-scattered from the scintillator layer are absorbed by the light-absorptive layer 22 such that the optical image emitted from the scintillator layer 7 comprises an image of point sources, thereby providing improved definition of the converted X-ray image. Suitable light absorptive layers 22 include dark coatings such as, for example, a thin carbon coating formed on the inside surface of the window 6. A suitable thickness for this layer 22 is 10 microns.

The embodiments of the present invention have been described with a buffer layer 8, as of magnesium oxide, aluminum oxide, or lithium fluoride. Such buffer materials are evaporated in vacuum onto the scintillator layer 7 to a suitable thickness such as 10,000 A. and preferably 1,000 A. less. Use of the buffer layer 8 is not a requirement and, in some instances, the photo cathode emitting layer 9 may be deposited directly upon the scintillator layer 7 in a manner as described and explained in copending U.S. patent application 606,513 filed Dec. 27, 1966 and assigned to the same assignee as the present invention.

As used herein, "X-ray" is defined to mean photons of an energy level equal to those of X-rays or higher. Thus, X-ray as used herein means not only X-rays but gamma rays and other high energy photons.

Since many changes may be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In an X-ray image intensifier tube, means forming an evacuated envelope having an aluminum X-ray transmissive window portion, means forming a scintillator layer of activated alkali metal halide material disposed inside said envelope and overlaying said X-ray window for converting X-ray images into optical images, means forming a photo cathode layer overlaying said scintillator layer for converting the optical images into electron images, means forming an electron accelerating and focusing electrode structure for accelerating the electron images to relatively high energy, means for picking up the high energy electron images for viewing, the improvement comprising, means forming a non-specular anodized surface formed on said aluminum window portion of said envelope, said scintillator layer being disposed abutting said non-specular surface of said window portion, and said anodized surface having a characteristic surface roughness greater than the wavelength of the optical photons emitted from said scintillator layer to inhibit light traveling in said scintillator layer.

2. In an X-ray image intensifier tube, means forming an evacuated envelope having an X-ray transmissive window portion, means forming a scintillator layer of activated alkali metal halide material disposed inside said envelope and overlaying said X-ray window for converting X-ray images into optical images, means forming a photo cathode layer overlaying said scintillator layer for converting the optical images into electron images, means forming an electron accelerating and focusing electrode structure for accelerating the electron images to relatively high energy, means for picking up the high energy electron images for viewing, the improvement comprising, means forming a non-specular light absorptive layer disposed intermediate said window portion of said envelope and said scintillator layer for absorbing the optical photons back-scattering from said scintillator layer to improve the definition of the optical image.

3. The apparatus of claim 2 wherein said light absorptive layer is a dark coating.

4. The apparatus of claim 3 wherein said light adsorptive layer is a layer of carbon.

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JAMES W. LAWRENCE, Primary Examiner

DAVID O'REILLY, Assistant Examiner

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250—213; 313—102, 116