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FLUORESCENT SCREEN FOR BRIGHTNESS AMPLIFIER TUBES AND METHOD OF MAKING THE SAME

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Fig. 1

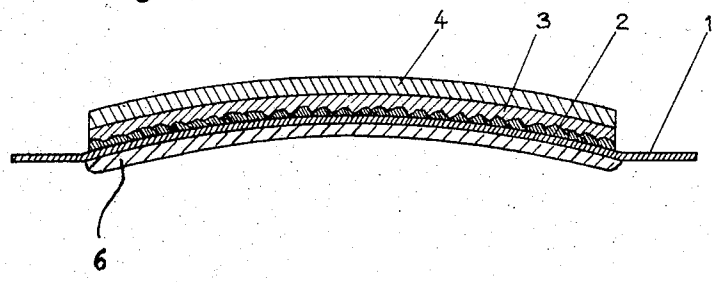
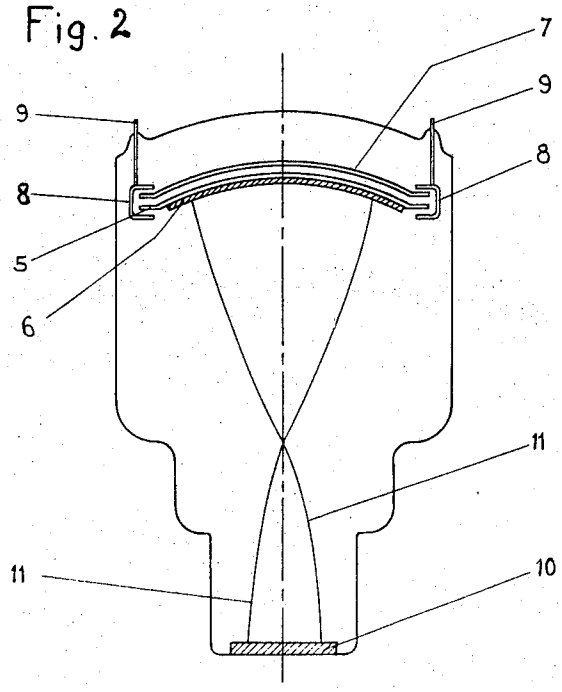


Fig. 2



INVENTOR

L. F. Guyot

By Holcombe, Wetherill & Brisebois

ATTORNEYS

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FLUORESCENT SCREEN FOR BRIGHTNESS AMPLIFIER TUBES AND METHOD OF MAKING THE SAME

Lucien Francis Guyot, Paris, France, assignor to Compagnie Francaise Thomson-Houston, Paris, France, a corporation of France

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4 Claims. (Cl. 117—33.5)

ABSTRACT OF THE DISCLOSURE

A fluorescent layer is bonded in an inorganic binder of borax or an alkaline-earth metal silicate; to form a smooth surface for further application of a reflective metal coating, a thin layer of silicone resin is applied over the fluorescent substance in the binder, over which a reflective surface of aluminum can then be applied.

This invention relates to brightness amplifier tubes and more especially to an improved construction of the primary fluorescent screen assemblies used therein. The invention was especially developed and has particular utility in connection with brightness amplifier tubes as used in X-ray systems.

A conventional brightness amplifier tube of the type to which the invention relates comprises a primary fluorescent screen assembly and a secondary screen spaced therefrom, both arranged in an evacuated envelope. The primary screen assembly comprises a glass plate having a fluorescent layer deposited on its radiation-input side (the side directed away from the secondary screen) and a photocathode layer on its output side. Radiations, such as X-rays, striking the fluorescent layer excite a primary image thereat and the light reemitted by the fluorescent layer strikes the photocathode which thereupon emits photoelectrons in numbers proportional, in each area of it, to the brightness of the fluorescent image. These electrons are accelerated and focussed by suitable electrodes and are directed on to the secondary fluorescent screen, forming thereon a secondary image of considerably increased brightness (or luminance). In order to improve the efficiency of the brightness amplification it is usual to provide over the primary fluorescent layer at the radiation-input side of the glass plate a thin coating of a metal that is transparent to the incoming radiations while being opaque and reflective to the light from the fluorescent layer so as to prevent any of the light therefrom straying in the direction away from the photo-cathode and being lost to the process.

The primary fluorescent layer comprises a coating of micro-crystals, of a suitable fluorescent substance such as zinc and cadmium sulfides in a suitable binder. The photocathode layer may comprise a layer of any of various suitable alkaline and other metals and their oxides. The glass plate, in addition to its function as a transparent support for the laminated assembly, serves also to prevent any undesirable chemical reactions between the constituents of the fluorescent screen and the photocathode. As the reflective coating aluminium can conveniently be used.

In the construction of brightness amplifiers of the type just described certain difficulties have been encountered, relating to the primary fluorescent screen and reflective metal coating provided on the radiation-input end of the amplifier tube.

The micro-crystals of fluorescent material must be firmly bonded amongst one another and also to the underlying glass plate surface and for this purpose an efficient binding substance must be used, which however must withstand

the relatively high temperatures encountered during the manufacture and service life of the amplifier tube without generating breakdown products.

Furthermore, it is essential that the reflective coating be also firmly bonded to the subjacent fluorescent layer. However, it is equally essential that the metallic substance used does not penetrate into the interstices of the crystals in said layer since this would impair the operation of the fluorescent screen; it is in fact essential that the inner surface of the metal coating adjacent the fluorescent layer shall be perfectly smooth in order that said coating shall effectively perform its reflective function.

It has not been found possible heretofore to meet the above conditions in a fully satisfactory way and without conflict. In some constructions, polymer resins have been used as the binder for the fluorescent crystals, including methyl methacrylate or silicone resin. Such binders provide a smooth interface bond with the overlying metal coating, and prevent diffusion of the metal into the crystals, but they are not stable at the relatively high temperatures encountered during the manufacture and use of the amplifier tube. At those temperatures vapors are generated from the substance itself and/or its breakdown products. These vapors undesirably affect the operation of the fluorescent and photo-emissive constituents in the tube. While it has been attempted to eliminate the volatile constituents of the binder itself or its breakdown products after deposition of the metal coating, complete elimination is practically impossible due to the depth of the fluorescent layer, and the above difficulty therefore remains.

To avoid this difficulty presented by organic and other polymer resin base binders, it has previously been proposed to use inorganic binders such as borax and alkaline-earth metal silicates, since these substances have good binding properties and withstand temperatures up to about 600° C. However, with the use of such binders, the resulting fluorescent coatings retain a granular structure with intercrystalline interstices of the order of 10 to 50 microns in width, so that the metal when coated over the surface of the fluorescent layer diffuses in between the crystal grains and these become embedded in metal and lose much of their fluorescent light-emissive capacity, while at the same time the reflectivity of the metal coating is impaired.

It has been attempted to eliminate this difficulty accompanying the use of otherwise desirable inorganic binders by depositing a layer of collodion over the fluorescent surface before applying the reflective metal coating, as by a wet process. After depositing the metal coating the assembly was subjected to a heat treatment for burning the collodion or sublimating it through the micro-pores present in the metal layer. The results however have been unsatisfactory. In the first place, immersion in water tends to disintegrate the fluorescent layer. Moreover, the thin collodion interlayer obtainable, which is of the order of a few microns in thickness, is inadequate to provide a smooth continuous film over the fluorescent layer wherein the irregularities as indicated above are about 50 microns wide, so that while this method does succeed in eliminating some of the diffusion of the metal into the inter-grain spaces, a satisfactorily smooth metallic surface cannot be obtained.

Objects of this invention are to eliminate the above-enumerated difficulties heretofore encountered in the manufacture of brightness-amplifier screen assemblies of the type described. Specifically, objects include the provision of an improved fluorescent screen assembly for a brightness amplifier tube, which has a fluorescent layer that is perfectly well bonded in a manner that will withstand all temperatures liable to be encountered in manufacture and use, and which will possess a smooth and continuous outer surface providing an ideal base for a re-

flective metal layer. Further objects lie in the provision of methods of making improved fluorescent screen assemblies having these advantages.

In accordance with the invention, the fluorescent screen assembly for a brightness amplifier tube of the kind described is formed by the combination of a fluorescent layer bonded by, an inorganic binder with a film of silicone resin applied over said fluorescent layer. A reflective metal coating is then deposited over the silicone resin film. The inorganic binder ensures satisfactory temperature stability and the silicone resin layer, without detracting from this temperature stability, provides a smooth continuous outer surface forming a perfect base for the overlying reflective layer completely preventing metal diffusion at the interface and assuring high reflectivity thereat.

An exemplary embodiment of the invention will now be described for purposes of illustration but not of limitation with reference to the accompanying drawings wherein:

FIGURE 1 is a large-scale sectional view of a primary fluorescent screen assembly for a brightness amplifier tube, and

FIGURE 2 is a simplified sectional view of an X-ray brightness amplifier tube embodying the improved fluorescent screen assembly.

Referring to FIGURE 1, in which the relative dimensions are shown off-scale for greater clarity, there is illustrated a fluorescent screen assembly including a glass plate **1** of slightly domed peripherally-flanged, shape, having on its concave side, which is the side from which the photo-electrons emerge in the operation of the device as later described, a photocathode layer **6** of any suitable well-known type and which does not form part of this invention. Applied to the convex, or X-ray beam-input, side of the glass plate **1**, is a layer **2** of fluorescent material; to the outer side of this layer is bonded an inter-layer **3** of silicone resin; and over this a reflective layer **4** of metal is coated.

The glass supporting plate **1**, e.g. about 0.1 to 0.2 mm. thick, consists of a soft grade of glass, e.g. lime glass, capable of withstanding chemical attack from the constituents of the adjacent layers especially the photocathode **6**. It may be shaped by pressure-molding at a suitable temperature.

The photocathode layer **2**, about 0.4 to 0.5 mm. thick, may comprise micro-crystals of zinc and cadmium sulfides, with some silver as an activator, and a binder which according to the invention may consist of borax in the form of micro-crystals considerably smaller in size than those of the fluorescent crystals, so as to fill the interstices between the latter and provide a firm bond between them and with the underlying glass surface. The resulting outer surface of the fluorescent layer **2** is rough and irregular, as depicted with some exaggeration in the drawing.

The silicone resin may comprise the commercial product identified and sold as "SI 804" by Dow Corning Corporation, Midland, Michigan, dissolved in a suitable organic solvent such as toluene, and is applied in a manner later described.

The metal layer **4**, about 20 to 30 microns thick may be aluminium.

The photocathode layer **6** may comprise a plurality of metals including at least one alkali metal, and its precise composition forms no part of this invention.

The silicone layer **3**, when applied in a manner to be presently described, fills all the depressions in the rough surface of the fluorescent layer **2**, completely preventing any diffusion of metal particles between the fluorescent crystal grains. At the same time its outer surface can be made perfectly smooth to impart high reflectivity to the metal coating thereover.

According to the invention, the following method may be used in construction the assembly shown in FIGURE 1.

An aqueous suspension is prepared containing zinc sulfide and cadmium sulfide crystals in a weight proportion of about 55% and 45% respectively, with the crystals being in the range of about from 20 to 40 microns in size, and containing a small quantity of silver as activator as well as a few parts per million of nickel for reducing image persistence. The solution further contains borax $B_4O_7Na_2.10H_2O$ dissolved therein in a proportion of from 60 to 120 grams per litre water. This suspension is deposited by sedimentation over the surface of the glass at a temperature of from 60 to 80° C. For obtaining the desired depth of 0.4 to 0.5 mm. the amount of fluorescent metal sulfides to be deposited on the glass is about from 50 to 100 mg. per $cm.^2$ area. The liquid is drained off and the residual borax crystallizes in the interstices of the sediment as it cools and dries, bonding the crystals in place.

The silicone resin, such as the SI 804 product mentioned above, dissolved in toluene, is then applied over the dry fluorescent layer as by gun-spraying, or other coating technique. The assembly is treated in a furnace at 400° C. for about one hour to polymerize the resin and eliminate the solvents. Thereafter the assembly is placed in a vacuum enclosure and a film of aluminium is deposited over the surface of the silicone resin coating by evaporation from a heated tungsten filament with a residual pressure of about 10^{-5} torr.

The assembly thus obtained, which constitutes a complete primary fluorescent screen except for the absence of the photocathode **6** on the under-surface of the glass supporting plate, is now assembled into a brightness amplifier tube as shown in FIGURE 2. The tube shown comprises a suitable and conventional vacuum enclosure having three suspension rods **9** extending vertically through and sealed in the upper end wall of the enclosure in angularly equispaced relation around its periphery, said rods having U-shaped suspension brackets **8** secured to their lower ends within the enclosure. The fluorescent screen assembly constructed as described above and generally designated **5** in FIGURE 2, is positioned so that the flat peripheral flange of the glass plate **1** thereof is clamped in the brackets **8**, together with an upper retainer and protective member **7** of a shape generally similar to that of the glass plate, and made of a suitable rigid material transparent to X-rays, such as suitable thin metal or glass plate. A conventional secondry fluorescent screen **10** is provided on the flat lower end of the tube enclosure. The photocathode **6** is applied to the under surface of the glass plate **1** of the primary screen assembly **5** within the tube enclosure by a suitable evaporation-coating process before the enclosure is finally sealed.

In the operation of the tube, a beam of X-rays from a source not shown is directed downwardly through the upper end wall of the tube and penetrates through the member **7**, reflective aluminium coating **4** and silicone layer **3** to the fluorescent layer **2**, where the beam excites a fluorescent image. The light rays are in turn converted to a corresponding beam of electrons in photocathode **6** as earlier indicated and the electrons are focalized and accelerated by a suitable field produced by electrodes, not shown, positioned around the electron beam so that said electrons follow paths such as schematically indicated at **11** and strike the secondary fluorescent screen **10** at the bottom of the tube there to provide a visible image of increased brightness.

A primary fluorescent screen when constructed as described above exhibits excellent performance. The inorganic binder imparts a strong bond to the fluorescent crystals among one another and with the underlying glass surface. The application of the thin film of silicone resin fills in any inter-crystalline cracks as well as the depressions in the rough outer surface of the fluorescent coating, preventing metallic particles from penetrating into said spaces during and after the metal coating step and providing a smooth under surface for the metal coating

which thus has heightened reflective ability. Only a very small quantity of silicone resin is required to be used according to the invention, so that the solvents and any volatile and unstable constituents are readily eliminated during the heating step, and no ingredients are retained that would be liable to impair the proper operation of the fluorescent screen or other components of the brightness-amplifier tube. An additional advantage of the silicone resin layer of the invention is that it possesses high toughness and resilience and is capable of withstanding heating to considerable temperatures without any formation of cracks or tendency to peel off.

It should be understood that various departures from the specific ingredients and details in the procedure and construction of the assembly described may be made without exceeding the scope of the invention. Thus, any suitable fluorescent materials other than the zinc sulfide and cadmium sulfide indicated may be used, such as calcium tungstate, as well as substances responsive to γ radiation such as sodium iodide and caesium iodide activated with thallium iodide. Similarly, the reflective metal coating may comprise, rather than the aluminium mentioned, any other metal having suitably low absorption to the radiations when present in the form of a thin film as well as a high reflective factor (higher than about 80%) to the light emitted from the fluorescent layer, as well as being substantially non-reactive with the constituents of the latter. Thus, in cases where the fluorescent layer comprises ingredients of the type including zinc and cadmium sulfides, activated with silver, and the screen fluoresces in the yellow-green portion of the spectrum, suitable metals include aluminium, copper, silver, chromium, nickel gold, indium. With a fluorescent constituent of the type including calcium tungstate activated with tungsten, emitting in the blue-violet band, the metals aluminium, silver, chromium, nickel, indium may be used.

As earlier mentioned, the invention may employ inorganic binders other than borax. Thus, binder substances such as silica and alkaline-earth silicates, which are substantially insoluble in water, are suitable. When the inorganic binder used is substantially insoluble in water, rather than soluble as is the case with the borax used in the example described in detail, then the invention contemplates a modification of the procedure described in the example. In this modification, the binder is formed in situ. Instead of depositing the fluorescent micro-crystals over the surface of the glass support by sedimentation directly from a suspension of said crystals in an aqueous solution of the inorganic binder compound (such as borax) as in the example described above, the said fluorescent micro-crystals are deposited on the glass plate by sedimentation from a suspension of said crystals in a water solution of an alkali metal silicate and an alkali-earth salt such as barium acetate. The reaction product, an insoluble alkaline-earth silicate, then precipitates from the solution and is deposited together with the fluorescent crystals on the surface of the glass plate to provide the desired binder. The subsequent steps of the procedure are similar to those previously described, that is the liquid is drained off and the assembly is dried, and the silicone resin layer is applied followed by the metal coating.

While the invention has been developed mainly in connection with primary fluorescent screens for X-ray brightness amplifier tubes, it may have other uses wherever it is desired to provide a fluorescent screen assembly including a fluorescent layer deposited on a transparent supporting plate and bearing a reflective metal coating on its outer surface. When applied to an X-ray brightness amplifier tube of the kind schematically shown in FIGURE 2, it will be understood that the secondary screen **10** is not necessarily of such type as to provide a visible image directly thereon, but may itself include a secondarily-emissive target surface capable of providing a visible image on some other screen, directly or by way of a television link.

I claim:

1. In a brightness amplifier fluorescent screen assembly comprising a supporting plate made from a material transparent to light rays, a photocathode element applied to one side of said plate, a layer of fluorescent crystals deposited on the opposite side of the plate, and a reflective metal coating overlying said layer, the improvement comprising the combination of an inorganic binder substance selected from the group consisting of borax and an alkaline earth metal silicate mixed with said layer for binding the crystals thereof, and a discrete substantially continuous film of silicone resin applied over said fluorescent crystal layer in said inorganic binder and disposed beneath said metal coating so as to be located therebetween to provide an unbroken separation between said layer and coating and a smooth reflective undersurface for said coating.

2. The improvement claimed in claim **1**, wherein said metal comprises aluminum.

3. In a method of producing a brightness amplifier fluorescent screen, the steps of preparing a suspension of micro-crystals of a fluorescent substance in an aqueous solution of borax, allowing the suspension to sediment over a surface of a glass plate, draining and drying whereby to provide a fluorescent layer over said surface wherein said micro-crystals are bonded to one another and to said surface by said borax, coating said layer with a solution of silicone resin in an organic solvent, heating the assembly to eliminate said solvent and set said resin to a thin film, and evaporation-depositing a thin layer of reflective metal over the smooth free surface of said silicone resin film.

4. In a method of producing a brightness amplifier fluorescent screen, the steps of preparing a suspension of micro-crystals of a fluorescent substance in an aqueous solution containing an alkali metal silicate and a soluble alkaline-earth metal salt, allowing the suspension to sediment over a surface of a glass plate and said silicate and salt to react and yield an insoluble alkaline-earth metal silicate, draining and drying whereby to provide a fluorescent layer over said surface wherein said micro-crystals are bonded to one another and to said surface by said alkaline-earth metal silicate, coating said layer with a solution of silicone resin in an organic solvent, heating the assembly to eliminate said solvent and set said resin to a thin film having a smooth free surface, and evaporation-depositing a thin layer of reflective metal over said free surface of the silicone-resin film.

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ALFRED L. LEAVITT, *Primary Examiner.*

A. H. ROSENSTEIN, *Assistant Examiner.*