

[54] **ELECTRON SCATTERING PREVENTION FILM AND METHOD OF MANUFACTURING THE SAME**

[75] Inventors: **Hideaki Mizuno**, Tokyo; **Naoki Akiyama**, Kanagawa, both of Japan

[73] Assignee: **Victor Company of Japan, Ltd.**, Kanagawa-ken, Japan

[22] Filed: **Apr. 16, 1971**

[21] Appl. No.: **134,653**

[30] **Foreign Application Priority Data**

Apr. 17, 1970 Japan..... 45/32837

[52] U.S. Cl. 117/33.5 CP, 117/33.5 C, 117/33.5 CM, 117/217, 250/71 R, 250/80, 313/92 PD, 313/92 PH, 313/108 A

[51] Int. Cl. **H01j 1/68**

[58] Field of Search..... 117/33.5 C, 216, 117/217, 219; 250/71 R, 80; 313/92 PD, 92 R, 92 PH, 108 A

[56] **References Cited**

UNITED STATES PATENTS

2,878,411	3/1959	Alvarez.....	313/92 PD X
3,515,587	6/1970	Letter.....	117/217
3,455,683	7/1969	Letter.....	250/80 X

Primary Examiner—Alfred L. Leavitt

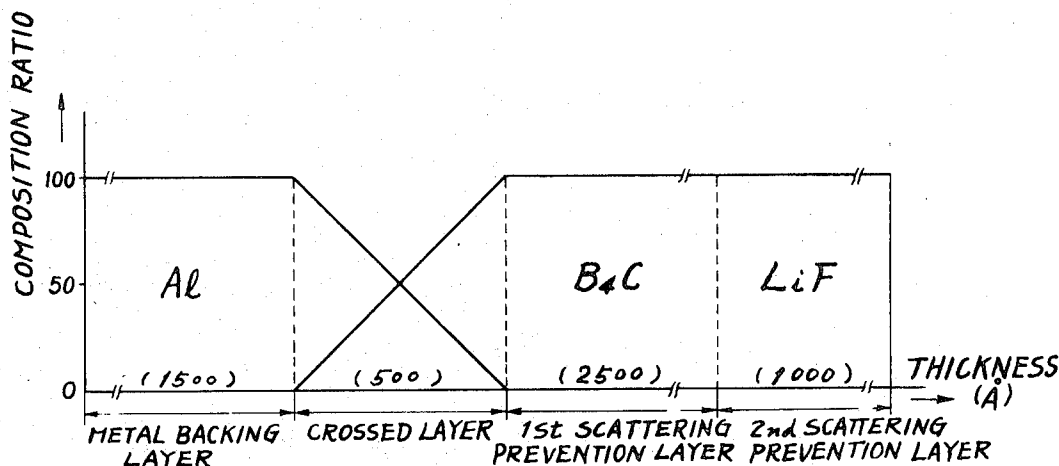
Assistant Examiner—Caleb Weston

Attorney—Holman & Stern

[57] **ABSTRACT**

An electron scattering prevention film in disclosed comprising at least the following three layers: an electrode layer deposited on a phosphor layer; a first electron scattering prevention layer deposited on the electrode layer composed of a first electron scattering prevention material having a smaller atomic number than that of the material constituting the electrode layer; and a second electron scattering prevention layer deposited on the first electron scattering prevention layer composed of a second electron scattering prevention material having a smaller atomic number than that of the material constituting the electrode layer. A bimetal action which occurs between the electrode layer and the first electron scattering prevention layer is cancelled by a bimetal action which occurs between the first electron scattering prevention layer and the second electron scattering prevention layer whereby the electron scattering prevention film is prevented from being distorted to an extent that the electrode layer peels off from the phosphor layer under variation of temperature.

4 Claims, 9 Drawing Figures



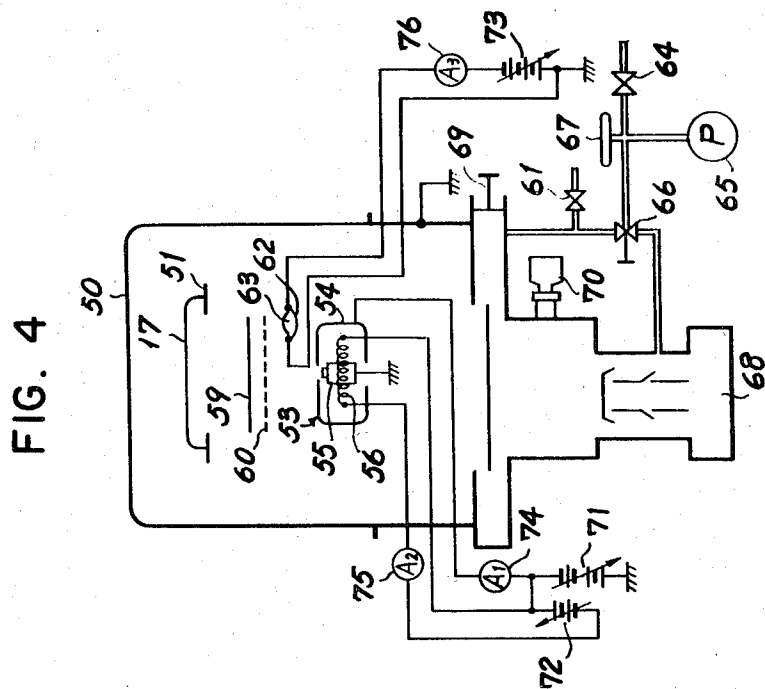
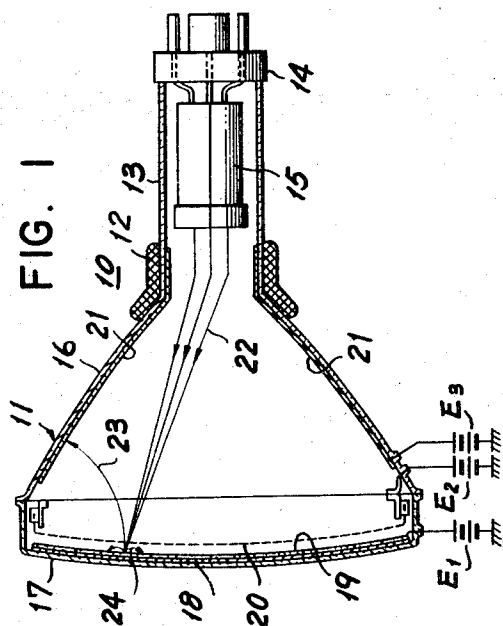


FIG. 2

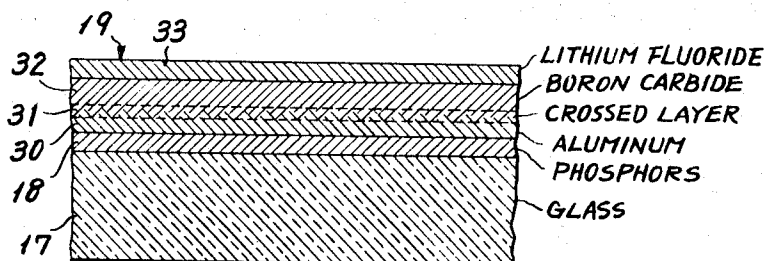


FIG. 3

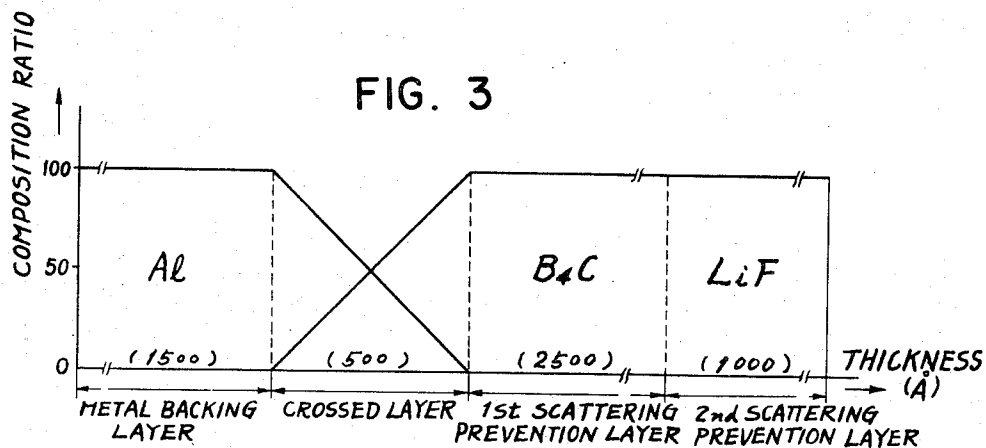


FIG. 9

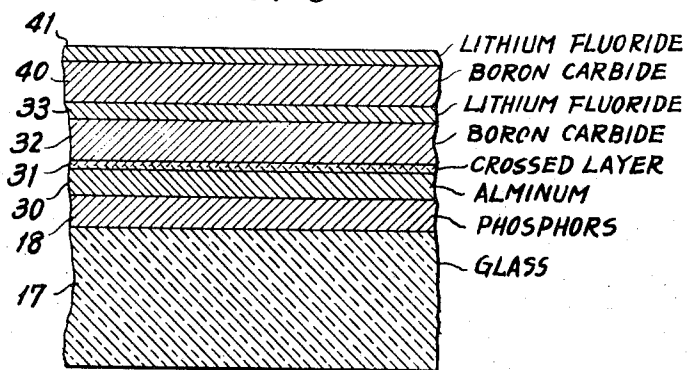


FIG. 5

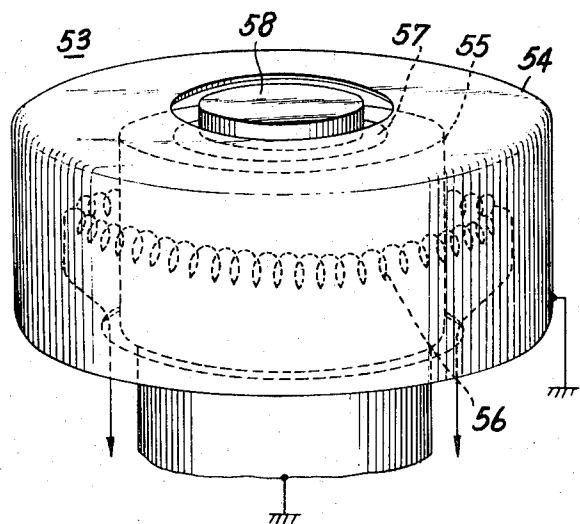
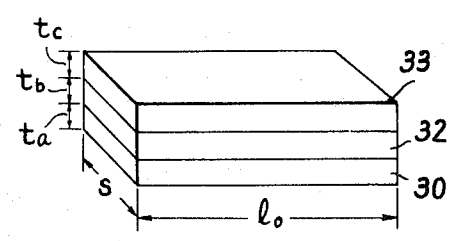
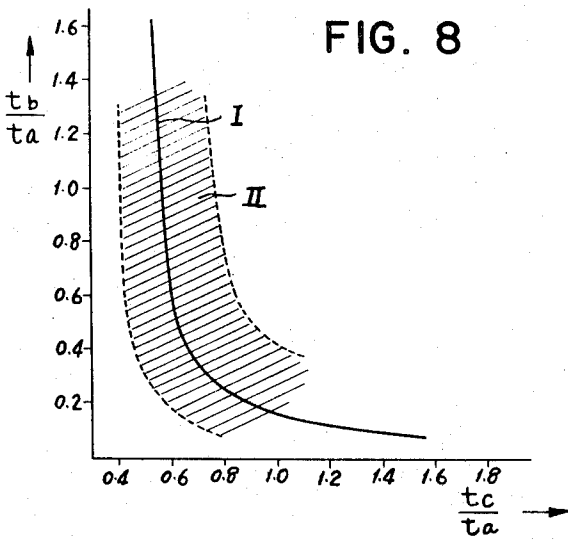
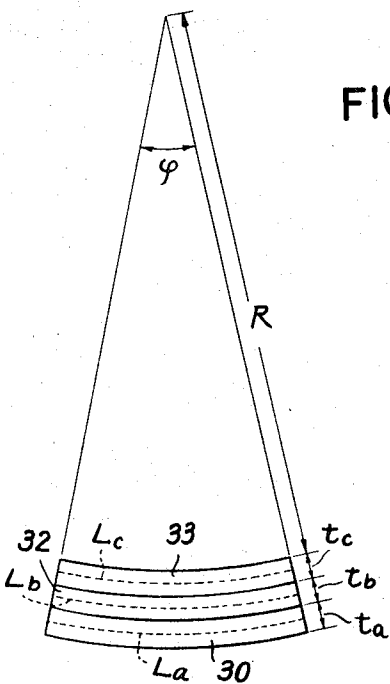


FIG. 6





ELECTRON SCATTERING PREVENTION FILM AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to an electron scattering and reflecting prevention film and a method of manufacturing the same, and more particularly to a film for use in color television picture tubes designed to minimize the reflection and scattering of electron beams and to prevent peeling off of a deposited film from a phosphor layer under variation of temperature.

Generally, in a post-acceleration color television picture tube, electron beams emitted from electron guns are accelerated in the accelerating field of a high voltage and strike a phosphor surface in electron beams of high kinetic energy exciting the phosphors to produce a luminous output. At the same time, a large number of secondary electrons, reflecting electrons and scattering electrons are generated by the impact of the electron beams of high kinetic energy.

These secondary electrons have no high kinetic energy as do the reflecting electrons. The secondary electrons, therefore, can be removed by utilizing the energy difference between the injected electrons and the secondary electrons. The scattering electrons, however, are accelerated by the post-accelerating field and strike the phosphor surface again with high kinetic energy of the same intensity as that of the incident electrons. As a result, halos take place around luminous points for the regular incident electrons. This deteriorates contrast of reproduced images and causes adverse color contamination.

In order to remove the phenomena, it has been proposed, as disclosed in U.S. Pat. No. 2,878,411, to provide an electron scattering prevention layer by sintering a single thin layer of material of small atomic number such as boron or carbon deposited on the metal backing of aluminum evaporated on the phosphor layer so that the amount of electrons scattering from the phosphor surface is reduced. However, this conventional electron scattering prevention layer made of a single thin layer is not capable of sufficiently preventing the scattering of electrons since the electrons are scattered at the boundary between the electron scattering prevention layer and the metal backing layer. This layer is also incapable of sufficiently absorbing the secondary electrons emitted from the shadow mask and has a further disadvantage that the single layer is apt to peel off during heating process in the manufacturing of the color television picture tube which is usually conducted under temperature of approximately 430°C and accordingly the manufacture is very difficult.

Furthermore, there is a tendency that the layer superposed upon the phosphor layer peels off more readily as the thickness of the superposed layer increases. In the meanwhile, the electron scattering prevention film must be of such a thickness that corresponds to the kinetic energy of the striking electrons so that the scattering of electrons will effectively be prevented. For example, phosphor screen voltage of the picture tube is in the order of 20 KV to 20-odd KV in which case the thickness of the electron scattering prevention film should be more than several thousand Å. However, the thicker the electron scattering prevention film, the greater is the stress between the material composing the electron scattering prevention layer and the material composing the metal backing layer due to differ-

ence in the coefficient of thermal expansion between the two materials. Consequently, the electron scattering prevention layer is more apt to peel off from the metal backing layer because of a bimetal action between the two layers. Owing to such disadvantages, the above described conventional film has not been put to practical use.

With a view to eliminating such disadvantages, the applicant proposed a film which is capable of effectively preventing scattering of electrons and which is much less likely to peel off than the conventional films and a method of manufacturing the same, in U.S. Pat. application Ser. No. 1,647 U.S. Pat. No. 3,692,576, filed Jan. 9, 1970, entitled "Electrons scattering prevention film and method of manufacturing the same." According to this proposed method, the electron scattering prevention film is manufactured by forming a crossed layer of aluminum (Al) and boron carbide (B₄C) between the metal backing layer of aluminum and the electron scattering prevention layer of boron carbide. This electron scattering prevention film is advantageous in that the electron scattering prevention layer is formed integrally with the metal backing layer through the crossed layer so that the electron scattering prevention layer hardly peels off from the metal backing layer.

However, this proposed electron scattering prevention film is not still free from the problem that the metal backing layer sometimes peels off from the phosphor layer during heating process due to a bimetal action which takes place between the metal backing layer and the electron scattering prevention layer. Generally, there is an innumerable number of projections and depressions on the surface of the phosphor layer and, if aluminum is evaporated directly upon the surface of the phosphor layer, the phosphor layer side of the aluminum thin film formed as a metal backing layer cannot be made as a mirror surface. Hence, in forming the metal backing layer on the phosphor layer, an intermediate film is first coated on the phosphor layer to make a flat surface and then aluminum is evaporated on this flat surface. The intermediate film is removed later by a baking treatment. Accordingly, adhesion of the metal backing layer produced in the above described manner to the phosphor layer is extremely weak. As a result, the metal backing layer easily peels off from the phosphor layer when the bimetal action takes place between the metal backing layer and the electron scattering prevention layer as described above. This causes a problem that precision is required in various manufacturing conditions with a resultant increase in the manufacturing cost.

SUMMARY OF THE INVENTION

It is, therefore, a general object of the present invention to provide a novel and useful electron scattering prevention film and a method of manufacturing the same eliminating the aforementioned disadvantages.

Another object of the invention is to provide an electron scattering prevention film and a method of manufacturing the same which film is capable of effectively preventing the scattering of electrons produced by the striking electron beams and in which an electrode layer does not peel off from a phosphor layer under variation of temperature.

A further object of the invention is to provide an electron scattering prevention film and a method of

manufacturing the same in which an electron scattering prevention layer does not peel off from an electrode layer and the electrode layer does not peel off from a phosphor layer under variation of temperature.

A still further object of the invention is to provide an electron scattering prevention film and a method of manufacturing the same which film is particularly useful in a post-acceleration color television picture tube.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the invention will become apparent from the description made hereinbelow with reference to the accompanying drawings, in which:

FIG. 1 is a vertical section of one embodiment of a post-acceleration color television picture tube having an electron scattering prevention film according to the invention;

FIG. 2 is an enlarged vertical section of a part of the picture tube screen having one embodiment of the electron scattering prevention film according to the invention;

FIG. 3 is a diagram showing a ratio of composition of evaporated film;

FIG. 4 is a schematic vertical section of one embodiment of an apparatus for manufacturing the electron scattering prevention film according to the invention;

FIG. 5 is a perspective view of a heating means for evaporating materials;

FIG. 6 is an explanatory diagram showing each layer of the evaporated film as a model;

FIG. 7 is a diagram for illustrating the state of each layer shown in FIG. 6 under a high temperature;

FIG. 8 is a graph showing the relationship between the relative thickness of the metal backing layer and the electron scattering prevention layer and the range in which the peeling off of the layer can be prevented; and

FIG. 9 is an enlarged vertical section of a part of a picture tube screen having another embodiment of the electron scattering prevention film according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

First, one embodiment of a post-acceleration color television picture tube having the electron scattering prevention film according to the invention will be illustrated with reference to FIG. 1.

A post-acceleration type color television picture tube 10 generally comprises a glass bulb 11 and is externally provided with a deflection yoke 12. Three electron guns provided on a connecting base 14 are sealed within neck 13 of the funnel. The bulb 11 generally comprises the funnel neck 13, a funnel 16 and a face plate 17. On the inner surface of the face plate 17 are disposed a phosphor layer 18 consisting of three color dot phosphors, i.e., of red, green and blue and an electron scattering prevention film 19 later described and formed integrally with a metal backing in accordance with the present invention. A shadow mask 20 which has apertures larger in diameter than each dot of phosphors of the phosphor layer 18 formed in correspondence to respective dot trios is provided spaced apart from respective layer 18 and film 19 and in parallel therewith.

According to one aspect of the present invention, a first electric power source E_1 is connected to a metal backing layer and a transparent conducting electrode such as a nesa glass. A second power source E_2 of 8.8 KV is connected to a shadow mask 20 and a third power source E_3 of 9.6 KV is connected to an anode 21 provided on the inner walls of the funnel 16. The power voltages E_1 to E_3 of the above power sources may preferably have the mutual relationships of $E_2 < E_3 < E_1$, so that there may be formed an intense post-acceleration electric field between the shadow mask 20 and the phosphor layer 18 with respect to the electron beams 22 emitted from the electron guns 15. Between the shadow mask 20 and the anode 21 is formed a weak negative acceleration electric field, which permits a major portion of the secondary electron 23 emitted from the shadow mask 20 when the electron beam 22 strikes at the shadow mask 20 to be absorbed in the anode 21.

Some of the secondary electrons generated from the surroundings of the apertures of the shadow mask 20 are drawn to the post-acceleration electric field between the shadow mask 20 and the phosphor layer 18, and enter the acceleration electric field through the apertures, where they are accelerated and strike the phosphor layer 18 partly causing deterioration of contrast. As the initial speed of the secondary electrons is about ten-odd volts when they are emitted from the shadow mask 20, the kinetic energy thereof is almost equivalent to the energy of the post-acceleration voltage when the secondary electrons strike at the phosphor layer 18 and said kinetic energy is smaller than that of the electron beams 22 striking the phosphor layer 18 through the shadow mask 20. By preferred selection of thicknesses of the metal backing layer evaporated on the phosphor layer 18 and the scattering prevention film it is possible to allow the primary electron beams 22 only to reach the phosphor screen 18 for illumination.

Thickness of the film coated on the phosphor layer 18 which may be enough to prevent the deterioration of contrast by the secondary electrons above described is about 5,000 A. in the conversion value of aluminum, where for instance the voltage of the phosphor layer is 20 KV and that of the shadow mask is 9 KV, and about 8,000 A. where the voltage of the phosphor layer is 25 KV and that of the shadow mask is 11 KV.

The electron beams of high kinetic energy passing through the shadow mask 20 and striking the phosphor emit a large number of secondary electrons and scattering electrons during striking the screen. Due to small initial speed these secondary electrons will neither excite nor illuminate the phosphor. The scattering electrons however are the electrons tending to disperse in diverse directions with nearly the same energy as of the incident electron beams. Hence, among the scattering electrons, electrons 24 emitted at angles larger than a critical angle (the angle is defined by the voltages of the phosphor layer and the shadow mask and the distance between the phosphor layer and the shadow mask) will draw a curved line in the post-acceleration electric field again to strike the phosphor layer almost losing no energy. As they do this, they cause halos surrounding the luminous point due to striking of normal electron beams. In consequence, the contrast of the image deteriorates and the color contamination takes place. As the scattering electrons 24 have nearly same energy as

the primary electron beams, the contrast and the color contamination can not be freed from the influence of said scattering electrons only by coating a thicker layer or film on the phosphor layer. This has been a major factor which has obstructed the practical use of the post-accleration color television tubes.

According to the present invention, an electron scattering prevention film is provided wherein the aforementioned secondary electrons are sufficiently absorbed, scattering electrons by the primary electron beams are not produced and an electrode layer such as a metal backing layer does not peel off from the phosphor layer under variation of temperature.

FIG. 2 shows a part of the electron scattering prevention film according to the invention in an enlarged vertical section. A metal backing layer 30 is formed by evaporating aluminum (Al) on the phosphor layer 18 by means of an evaporating means later described. On the metal backing layer 30 is continuously formed a crossed layer 31 which is composed of boron carbide (B_4C) used as a material having a small atomic number for preventing the scattering of electrons and aluminum in a mixed state. Then, a first electron scattering prevention layer 32 composed of boron carbide B_4C is formed continuously with the crossed layer 31. Further, a second electron scattering prevention layer 33 composed of lithium fluoride (LiF) having also a small atomic number is formed on the first electron scattering prevention layer 31. Thus, an electron scattering prevention film 19 which is integral with the metal backing layer 30 is constituted. The material composing the second electron scattering prevention film 33 (in the present embodiment, lithium fluoride LiF) is selected from among materials each having a different coefficient of thermal expansion and a smaller atomic number relative to the material composing the first electron scattering prevention layer 32 (in the present embodiment, boron carbide B_4C). It is to be understood that, if a reflecting electron emission ratio is in proportion to the atomic number, the atomic number required for obtaining a contrast ratio of 20 should be less than one half of the atomic number of aluminum (13). Besides, the material must be of characteristics which meet the various manufacturing conditions for the picture tube. Taking these conditions into consideration, the inventors have conducted experiments with materials such as B, C, LiF, $LiCO_3$ and B_4C . As a result, boron carbide B_4C and lithium fluoride LiF have been selected as most suitable materials.

The crossed layer 31 has, as shown in FIG. 3, a continuously varying density gradient of composite materials. Namely, from the metal backing layer 30 to the electron scattering prevention layer 32, in the diagram the composition ratio of aluminum gradually varies from 100 percent to 0 percent whereas the composition ratio of boron carbide varies from 0 percent to 100 percent. By forming the crossed layer 31 in the foregoing manner, possibility of undesired production of pin holes in the boron carbide layer 32 is eliminated. Accordingly, such an accident that the aluminum layer becomes transparent due to reaction of lithium fluoride LiF and aluminum Al through these pin holes can be avoided.

Next, the reason why the electron scattering prevention film 19 and the metal backing layer 30 having the foregoing construction are prevented from being distorted under variation of temperature to the extent that

they peel off from the phosphor layer 18 will be explained. For simplicity, the metal backing layer 30, the boron carbide layer 32 and the lithium fluoride layer 33 are treated in the form of a model as shown in FIG. 6. It is assumed that the crossed layer 31 is distributed to the metal backing layer 30 and the boron carbide layer 32. The thickness of each of the layers 30, 32 and 33 is respectively represented as t_a , t_b and t_c . The length of these layers is represented as l_0 and the width as s . It is assumed that the layers are stable in terms of dynamics, i.e., energy is minimum at a certain temperature θ_1 to θ_2 , the layers 30, 32 and 33 are distorted from the state as shown in FIG. 6 to the state as shown in FIG. 7 in which the layers are bent with a radius of curvature R and an angle ϕ , a state where energy stored in these layers is reduced to the minimum.

First the radius of curvature R is obtained and then conditions in which the radius of curvature R becomes infinite i.e., corresponding to the condition that the deposited film composed of the layers 30, 32 and 33 is not distorted, are obtained. Each constant to be used in the equation described later is represented as follows:

Initial temperature in the variation of temperature . . . θ_1

Final temperature in the variation of temperature . . . θ_2

Magnitude of the variation of temperature . . . $\Delta\theta = \theta_2 - \theta_1$

Coefficient of thermal expansion of the materials respectively composing the layers 30, 32 and 33 . . . $\alpha_a, \alpha_b, \alpha_c$ respectively The suffixes a , b and c correspond respectively to the layers 30, 32 and 33. The same is the case with suffixes used for each following constant.

Thickness of each of the layers 30, 32 and 33 . . . t_a, t_b, t_c

Young's modulus of composite material of the layers 30, 32 and 33 . . . E_a, E_b, E_c

Spring constant of each composite material of the layers 30, 32 and 33 . . . K_a, K_b, K_c

Length of the deposited film under the temperature θ_1 . . . l_0

Length if each of the layers 30, 32 and 33 existed alone under the temperature θ_2 , i.e., if the layers were not superposed one upon another . . . l_a, l_b, l_c

Average length of each of the layers 30, 32 and 33 at its center of thickness under the temperature θ_2 . . . L_a, L_b, L_c

Radius of curvature and angle of the bend of the deposited film under the temperature θ_2 . . . R and ϕ

First, the average lengths L_a , L_b and L_c of the respective layers 30, 32 and 33 at their center of thickness under the temperature θ_2 are respectively expressed by the following equations:

$$L_a = (R + t_a/2 + t_b + t_c)\phi \dots \quad (1-1)$$

$$L_b = (R + t_b/2 + t_c)\phi \dots \quad (1-2)$$

$$L_c = (R + t_c/2)\phi \dots \quad (1-3)$$

Again, lengths l_a , l_b and l_c of the respective layers 30, 32 and 33 under the temperature θ_2 if each of the layers existed alone are expressed by the equations;

$$l_a = l_0(1 + \alpha_a \Delta\theta) \dots \quad (2-1)$$

$$l_b = l_0(1 + \alpha_b \Delta\theta) \dots \quad (2-2)$$

$$l_c = l_0(1 + \alpha_c \Delta\theta) \dots$$

(2-3)

Further, from the relationship existing between spring constants and Young's modulus the following equations are obtained;

$$K_a = t_a/l_0 s E a \dots$$

(3-1)

$$K_b = t_b/l_0 s E b \dots$$

(3-2)

$$K_c = t_c/l_0 s E c \dots$$

(3-3)

Next, the change of internal energy in the respective layers 30, 32 and 33 accompanying the change of temperature from θ_1 to θ_2 can be considered as two separate changes, namely a change due to extension of the deposited film and a change due to bending thereof. The changes of energy due to extension are expressed by the equations;

$$U_{a1} = K_a/2 (L_a - l_a)^2 \dots$$

(4-1)

$$U_{b1} = K_b/2 (L_b - l_b)^2 \dots$$

(4-2)

$$U_{c1} = K_c/2 (L_c - l_c)^2 \dots$$

(4-3)

and the changes of energy due to bending are expressed

by the equations;

$$U_{a2} = 1/24 K_a \phi^2 t_a^2 \dots$$

(5-1)

$$U_{b2} = 1/24 K_b \phi^2 t_b^2 \dots$$

(5-2)

$$U_{c2} = 1/24 K_c \phi^2 t_c^2 \dots$$

(5-3)

The total change U of energy is obtainable by summing the foregoing equations (4-1), (4-2), (4-3), (5-1), (5-2) and (5-3) and can be expressed by the equation;

$$U = U_{a1} + U_{b1} + U_{c1} + U_{a2} + U_{b2} + U_{c2} \dots$$

(6)

Conditions under which the total change U of internal energy of the deposited film relative to the change of temperature of the deposited film is at the minimum can be obtained by the equations;

$$\delta U / \delta R = 0 \dots$$

(7)

$$\delta U / \delta \phi = 0 \dots$$

(8)

From the equation (7),

$$\delta U / \delta R = \phi [K_a \{(R + t_a/2 + t_b + t_c)\phi - l_a\} + K_b \{(R + t_b/2 + t_c)\phi - l_b\} + K_c \{(R + t_c/2)\phi - l_c\}] = 0 \dots$$

(9)

From the equation (8),

$$\delta U / \delta \phi = K_a [(R + t_a/2 + t_b + t_c) \{(R + t_a/2 + t_b + t_c)\phi - l_a\} + \phi/12 t_a^2] + K_b [(R + t_b/2 + t_c) \{(R + t_b/2 + t_c)\phi - l_b\} + \phi/12 t_b^2] + K_c [(R + t_c/2) \{(R + t_c/2)\phi - l_c\} + \phi/12 t_c^2] = 0 \dots$$

(10)

In order that U is held at the minimum, both equations (9) and (10) must hold at the same time.

From the equation (9),

$$\phi = 0 \dots$$

(11)

Or,

$$K_a \{(R + t_a/2 + t_b + t_c)\phi - l_a\} + K_b \{(R + t_b/2 + t_c)\phi - l_b\} + K_c \{(R + t_c/2)\phi - l_c\} = 0 \dots$$

(12)

Thus, two solutions (11) and (12) are obtained. If the equation (11); $\phi = 0$ is adopted, the following equation will result from the equation (10);

$$- \{K_a(R + t_a/2 + t_b + t_c)l_a + K_b(R + t_b/2 + t_c)l_b + K_c(R + t_c/2)l_c\} = 0 \dots$$

(10a)

However, since each constant of any actually available material is positive, it is apparent that the equation (10a) cannot hold by using an actually available material. Accordingly, the result of the equation (11); $\phi = 0$ cannot be adopted and the result which can be adopted is only $\phi \neq 0$.

Then, if ϕ is sought by adopting the equation (12),

$$\phi = \frac{K_a l_a + K_b l_b + K_c l_c}{K_a \left(R + \frac{t_a}{2} + t_b + t_c\right) + K_b \left(R + \frac{t_b}{2} + t_c\right) + K_c \left(R + \frac{t_c}{2}\right)}$$

(13)

However, if ϕ is sought by using the equation (10),

$$\phi = \frac{K_a l_a \left(R + \frac{t_a}{2} + t_b + t_c\right) + K_b l_b \left(R + \frac{t_b}{2} + t_c\right) + K_c l_c \left(R + \frac{t_c}{2}\right)}{K_a \left(R + \frac{t_a}{2} + t_b + t_c\right)^2 + \frac{t_a^2}{12} + K_b \left(R + \frac{t_b}{2} + t_c\right)^2 + \frac{t_b^2}{12} + K_c \left(R + \frac{t_c}{2}\right)^2 + \frac{t_c^2}{12}}$$

(14)

If the equation (13) is equal to the equation (14), the radius of curvature R of the deposited film when the total change U of the internal energy of the deposited film is minimum can be obtained. For simplicity of calculation, the following equations will be used:

$$P = K_a l_a + K_b l_b + K_c l_c \dots$$

(15-1)

$$Q = K_a + K_b + K_c \dots$$

(15-2)

$$V = K_a + l_a(t_a/2 + t_b + t_c) \dots$$

(15-3)

$$W = K_a/12 t_a^2 + K_b/12 t_b^2 + K_c/12 t_c^2 \dots$$

(15-4)

$$S = K_a(t_a/2 + t_b + t_c) + K_b(t_b/2 + t_c) + K_c(t_c/2) \dots$$

(15-5)

$$T = K_a(t_a/2 + t_b + t_c)^2 + K_b(t_b/2 + t_c)^2 + K_c(t_c/2)^2 \dots$$

(15-6)

From the equations (13), (14) and (15),

$$P/RQ + S = RP + V/R^2Q + 2RS + T + W \dots$$

(16)

From the equation (16), R is obtained by the equation;

$$R = VS - PW - PT/PS - VQ \dots$$

(17)

The value of R obtained from the equation (17) is the radius of curvature of the deposited film when the total change U of the internal energy of the deposited film is at the minimum.

If a condition under which the radius of curvature R becomes infinite is sought, the denominator of the equation (17) must be 0. Accordingly, this condition is given by the equation;

$$PS - VQ = 0 \dots$$

(18)

The equation (18) can be arranged using the original symbols and the following equation can be obtained;

$$t_a t_b (t_a + t_b) (\alpha_a - \alpha_b) E_a E_b + t_b t_c (t_b + t_c) (\alpha_b - \alpha_c) E_b E_c - t_a t_c (\alpha_c - \alpha_a) (t_a + 2t_b + t_c) E_c E_a = 0 \dots \quad (19)$$

In the above equation, the relationship between thicknesses of the layers is not clear. Hence, t_b and t_c are normalized by t_a and represented as $t_b/t_a = t'_b$ and $t_c/t_a = t'_c$. Then, the equation can be rewritten as follows;

$$t'_b (1 + t'_b) (\alpha_a - \alpha_b) E_a E_b + t'_b t'_c (t'_b + t'_c) (\alpha_b - \alpha_c) E_b E_c - t'_c (1 + 2t'_b + t'_c) (\alpha_c - \alpha_a) E_c E_a = 0 \dots \quad (20)$$

From the foregoing consideration, it will be possible to theoretically prove that in case layers consisting of plurality of different kinds of materials respectively having different coefficient of thermal expansion are formed as a film consisting of more than three layers deposited on a phosphor screen, the deposited film can be so constructed that it will not be distorted under variation of temperature by determining thickness of each layer in conjunction with the coefficient of thermal expansion and Young's modulus of the material composing each layer.

Physical constants of each material used in the embodiment having the above described construction are shown in the following table;

Material	Young's modulus (dyne/cm ²) (E)	Coefficient of thermal expansion (deg ⁻¹) (α)
Al	0.706×10^{12}	2.3×10^{-5}
B ₄ C	4.50×10^{12}	0.45×10^{-5}
LiF	0.880×10^{12}	3.7×10^{-5}

If the deposited film consisting of the three layers 30, 32 and 33 composed respectively of Al, B₄C and LiF is to remain undistorted under variation of temperature, the thickness of each layer must satisfy the equation (20). The graph shown in FIG.8 indicates relative thickness of the three layers in a state wherein the deposited film consisting of the three layers remains undistorted under variation of temperature, calculating the values by applying the constants of each material indicated in the above table to the equation (20) and taking the thickness of the aluminum layer 30 as a standard which is made one (1).

In FIG.8, $t'_c (=t_c/t_a)$, i.e., the thickness of the lithium fluoride layer 33 normalized by the thickness t_a of the aluminum metal backing layer 30 is indicated on the abscissa whereas $t'_b (=t_b/t_a)$, i.e., the thickness of the boron carbide layer 32 normalized by the thickness t_a of the aluminum metal backing layer 30 is indicated on the ordinate. A curve I shown by a full line in FIG.8 indicates a relationship between the thickness of the lithium fluoride layer 33 and the thickness of the boron carbide layer 32 respectively normalized by the thickness of the aluminum layer 30 in the state wherein the deposited film remains undistorted under variation of temperature. Accordingly, if the relative thicknesses of the layers 30, 32 and 33 are so selected as to satisfy the relationship indicated by the curve I shown by full line, stresses existing between each layer are cancelled with each other and the bimetal action which takes place between the layer 30 and the layer 32 is cancelled by the bimetal action which takes place between the layer 32 and the layer 33 whereby no distortion occurs in the deposited film.

A slight bending which may occur in the deposited film will not cause the deposited film to peel off from the phosphor layer by adhesion between the deposited

film and the phosphor layer if the degree of bending is small. In FIG.8, the shadowed portion II shown by oblique lines defined by dotted lines indicates the relative thickness between the layers 30, 32 and 33 at which there occurs a bending force in the deposited film which force is of a magnitude which is insufficient to cause the deposited film to peel off from the phosphor layer. Accordingly, the relationship between the thicknesses of the layers 30, 32 and 33 should be chosen within the shadowed portion II, most preferably on the curve I.

Specific numerical examples of preferable thickness of each layer will be given hereinbelow.

Examples:

	1	2	3	4
Thickness				
Whole deposited film	5500A.	5000A.	6500A.	3000A.
Layer 30 (Aluminum)	1500	1200	1700	1000
Layer 31 (Crossed layer)	500	500	800	600
Layer 32 (Boron carbide)	2500	2500	2500	900
Layer 33 (Lithium Fluoride)	1000	800	1500	500

In the foregoing embodiment, the deposited film is composed of three layers (i.e., the layers 30, 32 and 33) including the aluminum metal backing layer 30 but excluding the crossed layer 31. If the deposited film is to be made thicker (for example, approximately 1μ), the number of layers may be increased. Another embodiment of the construction of layers is shown in FIG.9. In this embodiment, a boron carbide B₄C layer 40 having a small coefficient of thermal expansion is superposed on the lithium fluoride LiF layer 33 constructed in the above described manner. Further, a lithium fluoride LiF layer 41 having a greater coefficient of thermal expansion is formed thereon. In this embodiment also, if the thicknesses of the layers 30 to 33 and 40, 41 are properly selected based on the relationship as described above, the deposited film can be so constructed as not to produce bending which will cause the deposited film to peel off from the phosphor layer.

Next, the method of manufacturing the electron scattering prevention film shown in FIG.2 and the apparatus for carrying out the method will be illustrated with reference to FIG.4 and FIG.5.

Air is introduced into the bell jar 50 through a leak valve 61 and after the pressure inside the bell jar 50 becomes the same as the atmospheric pressure the bell jar 50 is raised. A heating device 53 consists, as shown in an enlarged view in FIG.5, of a crucible 55 covered by an electrode 54 and a cathode filament 56 surrounding the crucible 55. A press formed boron carbide (B₄C, melting point 2450°C) 57 which has been sintered in argon gas under a temperature of 1300°C is placed in the crucible 55. A piece of solid aluminum (Al, melting point 660°C) 58 (for example 70mg) is placed on top of the boron carbide 57. On a boat 62 made of tantalum there is placed lithium fluoride (LiF, melting point 660°C). If the distance between the crucible 55 and the boat 62 is too great, the thickness of the film will become uneven whereas if the distance is too small the crucible 55 will be shaded by the boat 62. Accordingly, the distance should be properly selected. In the present embodiment, the distance is selected at 8 cm.

Further, the face plate 17 having a phosphor layer is supported by a support 51 provided in the bell jar 50.

The support 51 is spaced away from the crucible 55 and the boat 62 by about 20 cm to 30 cm.

Then the bell jar 50 is lowered. The leak valves 61 and 64 are closed. A rotary pump 65 is started in its operation and a valve 66 is opened whereby the bell jar 50 is preliminarily evacuated. The degree of the preliminary evacuation is checked by a Geissler tube 67 and, when the degree of vacuum has reached approximately 10^{-3} mm Hg, the valve 66 is changed over to a diffusion pump 68. Then, a main valve 69 is opened and the degree of vacuum in the bell jar 50 is increased to 2×10^{-6} mm Hg by the diffusion pump 68. This degree of vacuum is checked by a gauge 70.

After the degree of vacuum in the bell jar 50 has reached the aforementioned value, evaporation commences. The heater 56 is heated with voltage V_2 of a power source 72 being set at 7V and with electric current A_2 flowing through an ammeter 75 being set at 80A. Currents of thermions emitted from the heater 56 are bent by an electric field which is formed by the electrode 54 when voltage V_1 of a power source 71 is made 5KV and electric current A_1 flowing through an ammeter 74 is made 50mA. The bent currents of thermions concentrate upon the materials 57 and 58, striking and heating them.

A shutter 59 is closed and the materials 57 and 58 are pre-heated for 2 to 3 minutes. By this pre-heating, gases contained in the materials 57 and 58 escape therefrom. Aluminum 58 melts and a part thereof penetrates into boron carbide 57 to form a crossed part of the two materials. After pre-heating, the shutter 59 is opened and the voltage of the power source 71 is gradually increased from 5 KV to 8 KV during about 5 minutes. Then, aluminum 58 which is of a lower melting point first evaporates on the phosphor layer of the face plate 17, forming the aforementioned metal backing layer 30 with a thickness of 1500A.

The aforementioned 8 KV voltage is maintained for a further 5 minutes. The mixed part of the two materials then evaporates to form the crossed layer 31 in which aluminum and boron carbide are mixed together with the above described composition ratio gradient. The crossed layer 31 is continuously formed without having a definite boundary between the layer 31 and the metal backing layer 30 with a thickness of 500A.

Heating is further continued and all the aluminum evaporates. Then, the remaining boron carbide 57 evaporates to form the electron scattering prevention layer 32 continuously on the crossed layer 31 without having a definite boundary between the two layers with a thickness of 2500A.

When the boron carbide layer 32 has reached the aforementioned predetermined thickness, electric current flows through the boat 62 to heat it with voltage V_3 of a power source 73 being set at 2V and with electric current A_3 flowing through an ammeter 76 being set at 100 mA. Lithium fluoride 63 on the boat 62 evaporates by heating on the boron carbide layer 32 with a thickness of 1000A. A collector electrode 60 is provided to absorb leaking thermions and charged evaporation material molecules and maintained at earth potential or a suitably biased potential.

When the lithium fluoride layer 33 has reached the aforementioned thickness, evaporation is stopped. About 5 minutes later, the main valve 69 is closed and the leak valve 61 is opened. Atmosphere is introduced into the bell jar 50 which is then lifted up to enable the

face plate 17 to be taken out. It is to be noted that although the face plate 17 is not specially heated, temperature of the face plate 17 rises to about 50°C above room temperature due to factors such as radiant heat. The face plate 17 which has been taken out of the bell jar 50 is heated in the air at a temperature of 425°C for about one hour so as to frit-weld it with the funnel part.

In the foregoing embodiments, the present invention has been described with reference to a case in which the invention is applied to a post-acceleration color television picture tube. However, the invention is not limited to this but it is applicable to electron beam devices in which scattering of electrons caused by striking electron beams should be held to the minimum, particularly general cathode-ray tubes. Moreover, various modifications and variations of the invention will be apparent to those skilled in the art without departing from the scope of which is not forth in the appended claims.

What we claim is:

1. An electron scattering-prevention film deposited on a phosphor layer for an electron beam device, said film comprising a metallic electrode layer which is penetrable by primary electron beams and deposited on a phosphor layer, first electron scattering-prevention layer deposited on the metallic electrode layer, said first electron scattering-prevention layer being of a first compound of elements having a first atomic number less than the atomic number of the metal of the electrode layer, and a second electron scattering-prevention layer deposited on said first electron scattering-prevention layer, said second electron scattering-prevention layer being of a second compound of elements having a second atomic number less than the atomic number of the metal of the electrode layer, the first and second compounds being different from each other in atomic number said metallic electrode layer and said first electron scattering-prevention layer having therebetween a crossed layer which has a continuously varying composition from said first electron scattering-prevention layer to said metallic electrode layer ranging from zero to 100 percent of said metal and from 100 to 0 percent of said first compound, respective thicknesses of the metallic electrode layer and the first and second electron scattering-prevention layers being respectively of such values in connection with respective coefficients of thermal expansion and Young's modulus of the metallic electrode layer and the first and second electron scattering-prevention layers that a bimetal action which occurs between said metallic electrode layer and said first electron scattering-prevention layer is substantially cancelled by a bimetal action which occurs between the first and second electron scattering-prevention layers under variation of temperature whereby the electron scattering-prevention film comprising the metallic electrode layer and the first and second electron scattering-prevention layers do not peel off from said phosphor layer.

2. The electron scattering-prevention film as defined in claim 1 wherein the respective thicknesses of the metallic electrode layer and the first and second electron scattering-prevention layers satisfy a relationship expressed by or approximated by the following equation:

$$t'b(l + t'b)(aa - ab)EaEb + t'bt'c(t'b + t'c)(ab - ac)EbEc - t'c(l - 2t'b + t'c)(ac - aa)EcEa = 0$$

13

where $t'b = tb/ta'$, $t'c = tc/ta$; ta , tb and tc are thicknesses respectively of the metallic electrode layer, the first electron scattering-prevention layer; αa , αb and αc are coefficients of thermal expansion, and Ea , Eb and Ec are Young's moduluses respectively of the metal of the electrode layer, the first compound and the second compound.

3. The electron scattering-prevention film as defined in claim 1 further comprising a third electron scattering-prevention layer deposited on said second electron scattering-prevention layer, said third electron scattering-prevention layer being of the same compound as

14

the first compound, and a fourth electron scattering-prevention layer deposited on said third electron scattering-prevention layer, said fourth electron scattering-prevention layer being of the same compound as the second compound.

4. The electron scattering-prevention film as defined in claim 1 wherein the metal of the electrode layer is aluminum (Al), the first compound is boron carbide (B_4C) and the second compound is lithium fluoride (LiF).

* * * * *

15

20

25

30

35

40

45

50

55

60

65