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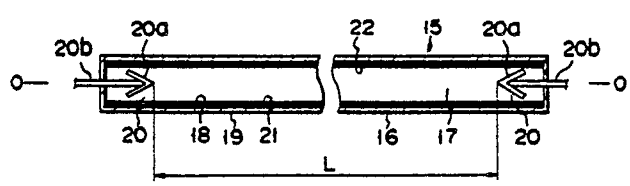
(54) Fluorescent lamp apparatus.

(57) A fluorescent lamp apparatus is disclosed which (15) includes a fluorescent lamp including a discharge tube (16) having a discharge space (17) filled with a gas conducive to light emission and electrodes (20) sealed one at each end of the tube and having a phosphor layer (21) coated on an inner surface (18) of the tube (16) and a high-frequency lighting circuit (30) for supplying a high-frequency electric power with a potential gradient set at over 5 V/cm, in which a light-transmitting electric insulation layer (22) is provided between the phosphor layer (21) and the inner surface (18) of the tube (16). The fluorescent lamp apparatus is of such a type that mercury ions within the discharge space (17) are prevented by the insulating layer from intruding in the wall of the tube (16).



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Fluorescent lamp apparatus

The present invention relates to a fluorescent lamp apparatus and, in particular, an apparatus including a fluorescent lamp which is operated with a high-frequency electric power.

A fluorescent lamp includes a discharge tube having having an elongated discharge space filled with a discharge gas conducive to light emission, electrodes sealed one at each end of the discharge tube and having a phosphor material coated on the inner surface of the tube. The two types of such lamps may be listed: a low-pressure mercury lamp using a starting rare gas, such as argon, and mercury for a discharge gas and a rare gas discharge lamp containing, for example, a neon gas primarily consisting of a xenon gas.

In this case, use may be made, as electrodes, of hot cathode type and a cold cathode type.

Such lamps are employed not only for an ordinary illumination purpose but also for a back light for a liquid crystal display unit or for a light source for a facsimile machine or for a scanning light source for a copying machine. The conventional lamp bulb for the back light and scanning light source was about 12 mm in inner diameter or over. A recent tendency is for the liquid crystal display unit, facsimile machine and copying machine to become more and more compact and increasingly thinner. This requires a compact and thinner lamp for a light source and hence smaller and thinner associated lighting circuit components.

In order to meet such requirements, lamps are so designed as to reduce the diameter of the discharge tube or to make themselves elliptical or somewhat flattened elliptical in cross-section. In an attempt to obtain more compact and thinner lighting circuit components, on the other hand, a high-frequency lighting system using, for example, a transistor inverter circuit has increasingly been adapted in place of the larger conventional lamps of a choke ballast type involving greater heat dissipation. Furthermore, the structure of the apparatus has been designed to be made more and more compact by reducing a lamp storage space and mounting the bulb in close proximity to the wall surface of a lamp storage of the apparatus.

In order to satisfy all these requirements simultaneously, the lumen maintenance factor is lowered, sometimes failing to maintain the luminous flux in better conditions until a rated service life of the lamp is ended.

That is, blackening occurs sometimes on the whole inner wall of the bulb during a portion of a lamp life, reducing the luminous flux. If the lamp is mounted on the wall of an apparatus of an electroconductive metal, blackening also occurs on the bulb wall surface portion corresponding to that electroconductive metal wall and a light emitting substance is sometimes dissipated within the discharge space with a resultant lowering of the illumination.

The aforementioned phenomena presumably occur for the reason as will be set forth below.

That is, for a discharge tube of a small diameter compared with that of a large diameter, a lamp voltage for maintaining a discharge level becomes a higher level and, for this reason, a potential gradient of (lamp voltage - voltage drop on electrode)/electrode-to-electrode distance along the axial direction of the tube becomes greater. For a conventional lamp of over 12 mm in diameter, the potential gradient is about 1 to 3 V/cm whereas, for a lamp of below 7 mm in diameter, the potential gradient is over 5 V/cm. When the lamp of such a high potential gradient is connected to the transistor inverter circuit and lit with a high-frequency electric power of above several KHz, an associated bulb of electrically insulating glass is electrically charged and hence conducts so that a leakage current flows from a discharge space toward the exterior of the lamp. As a result, the ions of the mercury which is filled within the discharge space are drawn by the leakage current toward the bulb wall and into the wall to produce a blackening phenomenon. If any xenon gas is filled within the discharge space, xenon gas ions are drawn by the leakage current into the bulb wall where they are dissipated.

Furthermore, if a conductor is situated in proximity to the exterior of the lamp, it acts as a proximity conductor, creating an electric field across the bulb and that conductor. Under the influence of the electric field, the ions of the mercury which is filled within the discharge space are drawn toward, and intrudes into, the bulb wall to develop blackening. In the case of a xenon gas, ionized xenon is drawn by an electric field toward the bulb wall and hence intrudes into the wall where it is dissipated.

The blackening of the gas and dissipation of the xenon gas cause a decline in the lumen maintenance factor.

It is accordingly the object of the present invention to provide a fluorescent lamp apparatus which prevents an intrusion of mercury ions and ionized xenon gas into the wall of a lamp bulb and hence prevents the blackening of the lamp bulb and dissipation of the xenon gas so that it is possible to enhance a lumen maintenance factor and to improve a lamp life.

According to the present invention, there is

provided a fluorescent lamp apparatus comprising:
a fluorescent lamp including a discharge tube filled with a discharge gas, a pair of electrodes provided within said tube and a phosphor layer coated on the inner surface of said tube; and means for applying a high-frequency electric power to said lamp,
characterized in that said fluorescent lamp includes an electrically insulating layer formed between an inner surface of said tube and the phosphor layer to allow light to be passed and said means for applying a high-frequency electric power is adopted to operate said lamp at a potential gradient set over 5 V/cm.

In the present invention, a light-transmitting insulating layer is provided between the phosphor layer and the inner surface of the tube to prevent a passage of a leakage current through the insulating layer and hence to prevent the mercury or xenon which are filled within the discharge space from intruding as ions into the bulb wall. It is thus possible to prevent blackening of the tube and dissipation of the xenon.

Also, according to the present invention, there is a fluorescent lamp apparatus comprising:
a fluorescent lamp including a discharge tube filled with a discharge gas, an electrode provided within said tube, a phosphor layer coated on an inner surface of said tube; and a proximity electroconductive member provided near an outer surface of said tube; and means for applying a high-frequency electric power to said lamp to operate said lamp,
characterized in that the fluorescent lamp includes an electrically insulating layer formed on a surface of said tube to allow light to pass.

Since, according to the present invention, a light-transmitting insulating layer is formed on the outer or the inner surface of the tube, even if an electric field is generated between the tube and a conductor member situated in proximity to the exterior of the tube, the gas which is filled within the discharge space is electrically shielded by that insulating layer against the electric field. It is thus possible to prevent the mercury or xenon ions from intruding into the wall and hence to prevent blackening of the tube and dissipation of the xenon gas.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective, exploded view showing a fluorescent lamp apparatus according to a first embodiment of the present invention;

Fig. 2 is a cross-sectional view, taken along line II-II in Fig. 1, showing the apparatus in an assembled state;

Fig. 3 is a cross-sectional view showing a fluorescent lamp of Fig. 1;

Fig. 4 is a circuit diagram showing a connection between a high-frequency transistor inverter circuit and fluorescent lamps;

Fig. 5 is a perspective, exploded view showing a fluorescent lamp apparatus according to a second embodiment of the present invention;

Fig. 6 is a cross-sectional view, taken along line VI-VI in Fig. 5, showing the apparatus in an. assembled state;

Fig. 7 is a cross-sectional view showing a fluorecent lamp apparatus, including a portion of a casing and a fluorescent lamp, according to a third embodiment of the present invention;

Fig. 8 is a cross-sectional view, including a portion of a casing and a fluorescent lamp, according to a fourth embodiment of the present invention;

Fig. 9 is a cross-sectional view showing a fluorescent lamp apparatus according to a fifth embodiment of the present invention; and

Fig. 10 is a circuit arrangement showing a connected structure, including a high-frequency transistor inverter circuit and a fluorescent lamp, according to a sixth embodiment of the present invention.

Fig. 1 shows an illumination apparatus used as a back light of a liquid crystal display apparatus, noting that the liquid crystal display apparatus is not shown. In an arrangement shown in Fig. 1, a casing 10 is made of synthetic resin, such as polycarbonate, mixed with a conductive material (not shown) of, for example, powdered aluminum, so as to prevent electrification and leakage of a high-frequency electromagnetic wave. The casing 10 is formed of a shallow pan with an upper side opened. A rib 11 which is triangular in cross-section is formed integral with a middle bottom of the casing 10. The bottom, side and rib surfaces of the casing 10 provide a reflection surface 12 which has a white color or a film evaporated with, for example, aluminum, over the whole area. Lamp support areas 13, 13, 13, 13 are formed two at each end wall of the casing 10 and have a trough configuration each. A pair of high-frequency lighting type fluorescent lamps 15, 15 according to the present invention are supported each on the opposite pair of lamp support areas 13, 13.

The fluorescent lamp 15 is of such a straight line type as indicated by a cross-section in Figs. 2 and 3 and includes a discharge tube or a bulb 16. The bulb 16 is constructed of a straight glass tube having one end and an other end with an axis defined therebetween. The tube 16 has a discharge space 17 across both the ends thereof and an inner surface 18 facing the discharge space 17 and an outer surface 19 facing the outside.

A pair of electrodes 20, 20 are provided within the tube 16 such that each is provided at the corresponding end of the tube. The electrodes 20, 20 are of a cold-cathode type in the embodiment of the present invention and comprise an electrode body 20a constructed of an arrow like nickel plate and a lead wire 20b connected to the electrode body 20a. An axial distance defined between the tips of the arrow-like electrodes is denoted by L (cm).

A phosphor material 21 is coated on that inner surface 18 of the tube 16 which faces the discharge space 17. As the phosphor material 21 use is made of, for example, calcium halophosphate which is formed as a layer on the inner surface 18 of the tube 16.

Within the discharge space 17 of the tube 16, a predetermined amount of mercury and a starting rare gas, such as argon, xenon etc., are sealed as materials for sustaining a discharge.

A light-transmissive, electrically insulating layer 22 is formed between the inner surface 18 of the tube 16 and the phosphor layer 21. The insulating layer 22 is formed of a light-transmissive metal oxide, such as alumina, silica, zirconia and cerium oxide.

As the insulating layer 22 a powered-alumina layer is employed according to the present invention.

The insulating layer 22 made of the alumina can be formed by preparing, for example, a suspension of powdered alumina and nitro-cotton in butyl acetate, coating the suspension on the inner surface 18 of tube 16 and sintering the coated film into ceramics.

As another method, an alumina layer can be formed on the inner surface 18 of the tube 16 by dipping a tube 16 into an organic alumina compound solution, such as an aluminum alcoxide solution, and lifting, drying and sintering it.

A fluorescent lamp 15 according to the present invention includes a bulb of a substantially circular cross-section having an outer diameter d_1 of 6.5 mm and inner diameter d_2 of 5.0 mm in which case the whole length of the bulb is 270 mm and an electrode-to-electrode length L is set to be 250 mm.

When the fluorescent lamp is lit, at a no-load state, with an effective voltage of 800 V applied thereto, the lamp current and voltage become 7 mA and about 300 V (effective value). At this time, a 13tential gradient in the tube 16 becomes about 8 V/cm (11.3 V/cm at a peak value), a value which is obtained by subtracting a voltage drop on electrode from the lamp voltage value and dividing an obtained value by the electrode-to-electrode distance L.

The ends of the lamps 15, 15 are firmly fitted in the corresponding lamp support areas 13, 13, 13, 13 of the casing 10.

A light diffusion transmission plate 25 is attached to an upper open end of the casing 10, noting that the plate 25 is made of, for example, an acrylic resin. The acrylic resin has a milky white color and a function of allowing light to be transmitted in a diffused fashion. At the undersurface (or an upper surface) of the transmission plate 25, thickened portions 26, 26 are formed which face the lamps 15, 15, respectively. The thickened portions 26, 26 extend along the axial direction of the lamps 15, 15 with their thickness gradually decreased away from a direction perpendicular to the axial direction of the lamps 15, 15.

A high-frequency electromagnetic wave preventing section 27 is provided on the upper surface of the transmission plate 25. The section 27 is formed by evaporating aluminum on the upper surface of the transmission plate 25 in a mesh-like fashion and prevents an external leakage of a high-frequency electromagnetic wave because it is made up of an aluminum conductor.

The fluorescent lamps 15, 15 are connected respectively through ballast elements 31,31 to a high frequency transistor inverter circuit 30 and lit via this circuit. The high-frequency transistor inverter 30 is connected to a power source 32. In this connection, the lighting frequency is 50 KHz in the embodiment of the present invention.

The fluorescent lamp apparatus thus constructed will be explained below.

When a voltage of a power source 32 is applied to the fluorescent lamps 15, 15 through the high-frequency transistor circuit 30, then the lamps 15,15 are lit.

Some of light which is emitted from the lamps 15, 15 is reflected on the reflection surface 12 which is formed on the bottom surface and rib 11 of the casing 10, and directed toward the open top and hence the transmission plate 25. The remaining light is directed directly toward the transmission plate 25 so that all of the light emitting from the lamps 15, 15 is externally directed through the transmission plate 25 for illumination.

Since, in this case, the thickened portions 26,26 are formed on the inner surface of the transmission plate 25 over the lamps 15, 15, an amount of transmission light is reduced at the thickened portions 26,26. Furthermore, the transmission plate 25 increases in its amount of light transmission as the thickness of the plate 25 is decreased in a direction away from a top plane just over the lamps 15,15. Thus the transmission plate 25 per se serves to eliminate a luminance variation.

For this reason, the luminance distribution of light which is emitted via the transmission plate 25 provides uniform brightness over the whole surface of the transmission plate 25.

In order to prevent electrification and leakage of a high-frequency wave, the casing 10 contains powdered aluminum and the mesh-like leakage preventing section 27 is formed on the top surface of the transmission plate 25. For this reason, even if the fluorescent lamps 15, 15 are lit with a high-frequency wave within the casing 10, an external leakage of the high-frequency electromagnetic wave is prevented.

It has been found that, even if about 15000 hours elapses after the start of lighting, the luminous intensity of the lamps 15,15 maintains a value of over 50% relative to an initial luminous intensity and that a high lumen maintenance factor is ensured due to less blackening on the wall of the bulb.

In contrast, in the case of a lamp of such a type that there is no insulating layer 22 made of alumina, blackening is started about several tens of hours after the lighting of the lamp and the luminance intensity is lawed to 50% of its starting level after a lapse of about 300 hours.

From this it will be appreciated that the lamp of the present invention is very effective.

The aforementioned advantage is obtained probably due to the cause as will be set forth below.

That is, if the insulating layer 22 is formed between the inner surface 18 of the tube 16 and the phosphor layer 21, it prevents the electric conduction of a glass tube 16, that is, passage of a leakage current. This prevents the ions of the mercury which is filled within the discharge space 17 from entering the bulb wall and prevents blackening on the bulb wall. It is thus possible to improve the lumen maintenance factor and to extend the lamp life.

This presumption is supported by the fact that, if, unlike the present embodiment, the fluorescent lamp 15 not having such a light-transmissive, insulating layer 22 as in the present embodiment is lit with a commercial power supply of 50 Hz and choke ballast, no blackening is observed even about 3000 hours after the lighting of the lamp. This will be probably because, although the intensity of an electric field in the discharge space 17 of the bulb 16 is substantially the same as in the high-frequency lighting type lamp of the present invention, the leakage current is decreased to an extremely small extent due to the lower frequency involved.

From this it will be seen that the present invention can effectively be applied to the fluorescent lamp to which high-frequency power is supplied from a high-frequency generator.

Thus the presence of the insulating layer 22 between the inner surface 18 of the tube 16 and the phosphor layer 21 prevents blackening from occurring on the bulb wall, ensuring an improved lumen maintenance factor and a prolonged lamp life.

A second embodiment of the present invention will be explained by reference to Figs. 5 and 6.

The second embodiment is different from the first embodiment of the present invention in that a fluorescent lamp 15 is of a U-bent type, that a stripe-type leakage preventing section 28 is formed on a light diffusion type transmission plate 25 to prevent a leakage of a high-frequency electromagnetic wave, and that a starting proximity conductor 40 is attached to the undersurface of an external surface 19 of a tube 16 so as to ensure a better startability.

In the second embodiment, the aforementioned U-bent type fluorescent lamp 15 is enclosed within a casing 10 similar to that of the first embodiment, and the aforementioned transmission plate 25 is provided at the upper open end of the casing 10.

The leakage preventing section 28 which is provided on the transmission plate 25 is comprised of a stripe-like aluminum-deposited section on the undersurface of the transmission plate 25. That stripe pattern is of such a type that the pitch is dense just over the lamp 15 and gradually coarser in a direction away from the lamp 15.

In the lamp 15, a starting proximity conductor 40 is attached to the undersurface of an outer surface 19 of the U-shaped bulb 16 along the axial direction of the lamp 15. The proximity conductor 40 is an aluminum tape about 2 mm in width which is attached to the bulb along the axial direction of the bulb 16 with one end of the tape connected to one electrode 20 to obtain the same polarity as that electrode.

The lamp 15 of this embodiment has a light transmission insulating layer 22 formed between the inner surface 18 of a tube of the fluorescent lamp and a phosphor layer 21.

The tube of the fluorescent lamp 15 has an inner diameter of 6.5 mm, a lamp current of 15 mA and a potential gradient is 6 V/cm at a peak level.

The fluorescent lamp 15 was connected to the same high-frequency transistor inverter circuit 30 as that of Fig. 4 and lit when a high-frequency wave of 42 KHz is applied from the high-frequency transistor inverter circuit 30.

Under the aforementioned conditions, when the lamp with no light transmission insulating layer formed thereon was lit, intense band-like blackening occurred along the starting proximity conductor (40) 1000 hours after the lighting of the lamp. Minor blackening was also observed on that lamp surface portion corresponding to the transmission plate 25.

It is understood that, owing to the proximity conductor 40 and stripe-like high-frequency electromagnetic wave leakage preventing section 28 both comprised of a conductor, an electric field occurs relative to the tube 16 so that memory ions are migrated, while being drawn toward the bulb wall, into the bulb wall to produce blackening.

In contrast, when use was made of the lamp of the present invention including the light transmission insulating layer 22, blackening on the bulb wall was not observed 8000 hours after the lighting of the lamp. This is because the light transmission insulating layer 22 allows no electric field to be created between the outer surface 19 of the tube 16 on one hand and the electric conductors, for example, the proximity conductor 40 and leakage preventing section 28 on the other hand to prevent the mercury ions from being drawn toward the bulb wall and hence to prevent the occurrence of blackening.

Since, in the case of the second embodiment, the starting proximity conductor 40 and leakage preventing section 28 are the conductors and since, due to the proximity of these conductors to the tube 16, an electric field is created between these conductors and the tube 16 to produce blackening, a potential gradient along the axis of the tube is not restricted in this case to over 5 V/cm.

A third embodiment of the present invention will be explained below by reference to Fig. 7.

The third embodiment is different from the second embodiment in that a light transmission insulating layer 22 is formed on an outer surface 19 of a tube 16. The fluorescent lamp of the third embodiment is placed in the same casing 10 as that of the second embodiment. In this case, the distance ℓ between the outer surface 19 of the tube 16 and a reflection surface 12 of the casing 10 is set to be 5 mm.

This lamp 15 was connected to the same high frequency transistor inverter circuit 30 as in Fig. 4 and a high-frequency wave of 42 KHz was applied from the transistor inverter circuit 30 to the lamp to light the lamp at a lamp current of 15 mA.

No blackening was observed on the wall of the bulb even 8000 hours after the lighting of the lamp 15.

That is, it is understood that the same advantage can be gained even if the light transmission insulating layer 22 is formed on the inner surface 18 or the outer surface 19 of the tube 16.

A fourth embodiment of the present invention will be explained below with reference to Fig. 8.

The fourth embodiment of the present invention is different from the third embodiment in that a tube 50 of the lamp 15 is elliptical in cross-section and that a light transmission insulating layer 22 is formed between an inner surface 18 of the tube 50 and a phosphor material 21.

The elliptical type tube is 14 mm in an inner major diameter as indicated by a and 6 mm in an inner minor diameter as indicated by b in Fig. 8. The fluorescent lamp (the fourth embodiment) 15 was placed within the same casing as that of the second embodiment of the present invention in which case a distance ℓ between an outer surface 19 of the tube 50 and a casing 10 was set to be 5 mm.

When the fluorescent lamp (the fourth embodiment) was lit at a lamp current of 30 mA with a frequency of 42 KHz, no blackening was observed 5000 hours after the lighting of the lamp.

When, on the other hand, the lamp was used with no light transmission insulating layer formed thereon, blackening occurred on that wall surface of the tube 50, 200 hours after the lighting of the lamp, which corresponds to a reflection surface 12.

Fig. 9 shows a fluorescent lamp according to a fifth embodiment of the present invention. A somewhat flattened tube 51 elliptical in cross-section may be employed in place of the aforementioned elliptical tube of Fig. 8.

A sixth embodiment of the present invention will be explained by referring to Fig. 10.

In the sixth embodiment, an internal electrode 60 is provided only at one end of a tube 16 of a fluorescent lamp 15 and an external electrode 61 formed of a metal paste is provided on the outer surface of the tube 16 along the axis of the tube 16.

The fluorescent lamp having a tube (16) 4 mm in inner diameter and a length of 100 mm was lit at a lamp current 5 mA with a high frequency.

In a conventional lamp with no light transmission insulating layer 22 thereon, blackening started to occur several hours after the lighting of the lamp whereas, according to the present invention, the lamp having a light transmission insulating layer 22 causes no blackening even 5000 hours after the lighting of the lamp.

From the explanation of the aforementioned respective embodiments is will be understood that the blackening of the bulb promptly occurs when the lamp is lit at a potential gradient of over 5 V/cm with a high frequency and that, in order to prevent blackening, it is effective to form the light transmission insulating layer 22 on the inner surface of the tube.

It will also be understood that, even if the fluorescent lamp which is placed at a distance of below 10 mm relative to the external conductor is lit with a high frequency, the blackening of the bulb is produced but that, even in that case, the blackening phenomenon is effectively prevented by forming the light transmission insulating layer 22 on the inner or the outer surface of the tube.

The discharge tube, if being circular, elliptical or somewhat flattened elliptical in cross-section, may be used in the present invention. Since a lamp voltage is high for a tube of a circular cross-section whose inner diameter is below 7 mm and for a tube of an elliptical or a substantially flattened elliptical configuration whose minor diameter is below 7 mm, the present invention can particularly effectively be carried out.

The present invention can also be applied to a rare gas discharge type fluorescent lamp of such a type that no mercury is filled within a tube. In such a fluorescent lamp, no blackening takes place due to the absence of any mercury and hence to no migration of mercury ions into the wall of the bulb. For the rare gas discharge lamp, however, xenon ions are migrated into the wall of the bulb and dissipated there, causing a decrease in the flux of light and hence degrading an expectant life characteristic. In order to prevent this, it is effective to provide a light transmission insulating layer.

The fluorescent lamp of the present invention may be not only of a cold cathode type but also of a hot cathode type.

Claims

1. A fluorescent lamp apparatus comprising:
a fluorescent lamp (15) including a discharge tube (16, 50, 51) filled with a discharge gas, a pair of electrodes (20, 20) provided within said tube (16, 50, 51) and a phosphor layer (21) coated on the inner surface (18) of said tube (16, 50, 51); and
means (30) for applying a high-frequency electric power to said lamp;
characterized in that said fluorescent lamp (15) includes an electrically insulating layer (22) formed between an inner surface (18) of said tube (16, 50, 51) and the phosphor layer (21) to allow light to be passed and said means (30) for applying a high-frequency electric power is adopted to operate said lamp (15) at a potential gradient set over 5 V/cm.

2. The apparatus according to claim 1, characterized in that said discharge gas contains mercury.

3. The apparatus according to claim 1, characterized in that said discharge gas contains xenon.

4. The apparatus according to claim 1, characterized in that said electric insulating layer (22) is formed of powdered alumina.

5. The apparatus according to claim 1, characterized in that said tube is circular in cross-section and below 7 mm in inner diameter.

6. The apparatus according to claim 1, characterized in that said tube is elliptical in cross-section and has a major diameter and a minor diameter of below 7 mm.

7. A fluorescent lamp apparatus comprising:
a fluorescent lamp (15) including a discharge tube (16, 50, 51) filled with a discharge gas, an electrode (20, 60) provided within said tube (16, 50, 51), and a phosphor layer (21) coated on an inner surface (18) of said tube (16, 50, 51); and
a proximity electroconductive member (10, 40, 61) provided near an outer surface (19) of said tube (16, 50, 51); and
means (30) for applying a high-frequency electric power to said lamp to operate said lamp (15),
characterized in that the fluorescent lamp (15) includes an electrically insulating layer (22) formed on a surface (15, 19) of said tube (16, 50, 51) to allow light to pass.

8. The apparatus according to claim 7, characterized in that said electrical insulating layer (22) is formed between an inner surface of said tube and said phosphor layer (20).

9. The apparatus according to claim 7, characterized in that said electrical insulating layer (22) is formed on an outer surface (19) said tube.

10. The apparatus according to claim 7, characterized in that a distance between an outer surface (19) of said tube (16, 50, 51) and said proximity electroconductive member (10, 40, 61) is below 10 mm.

11. The apparatus according to claim 10, characterized in that said proximity electroconductive member is an external electrode (61) which causes a discharge relative to said electrode.

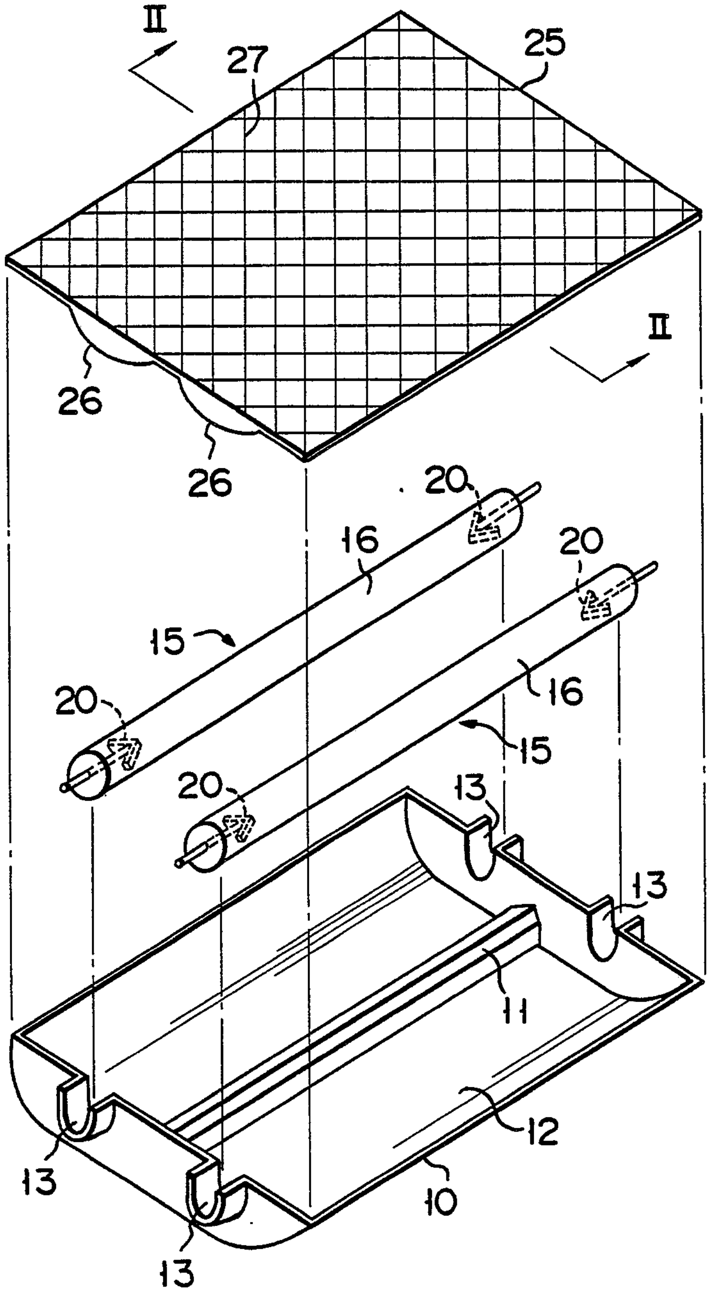
12. The apparatus according to claim 7, characterized in that said discharge gas contains mercury.

13. The apparatus according to claim 7, characterized in that said discharge gas contains xenon.

14. The apparatus according to claim 7, characterized in that said electric insulating layer is powdered alumina.

15. The apparatus according to claim 7, characterized in that said tube (16) is circular in cross-section and below 7 mm in inner diameter.

16. The apparatus according to claim 8, characterized in that said tube is elliptical in cross-section and has a major diameter and a minor diameter of below 7 mm.



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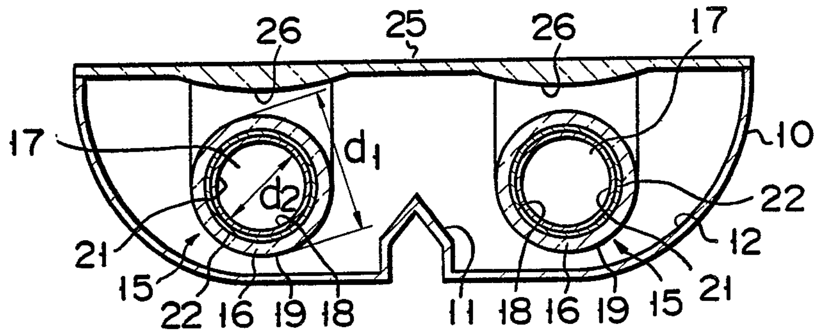


FIG. 2

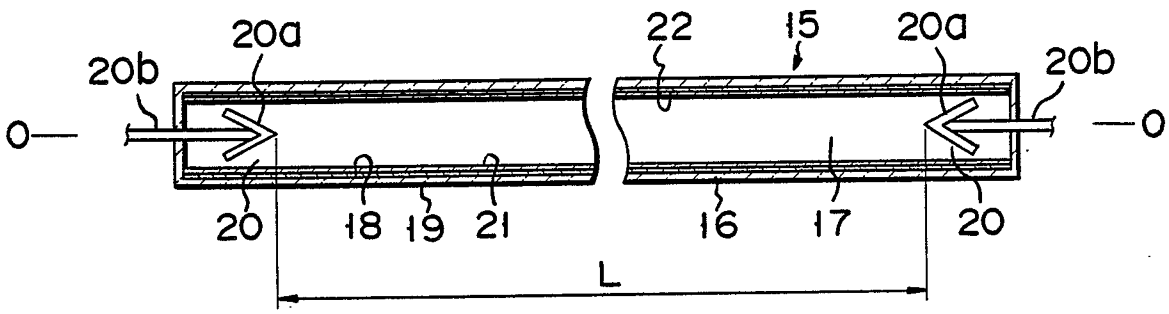


FIG. 3

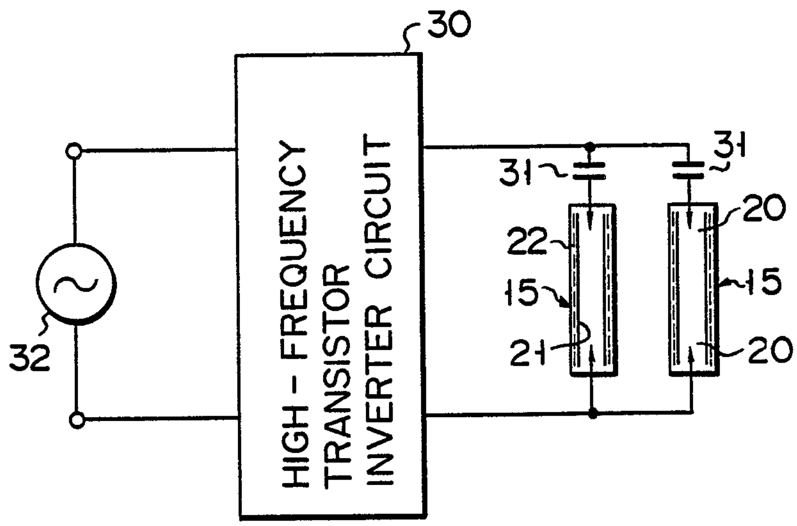


FIG. 4

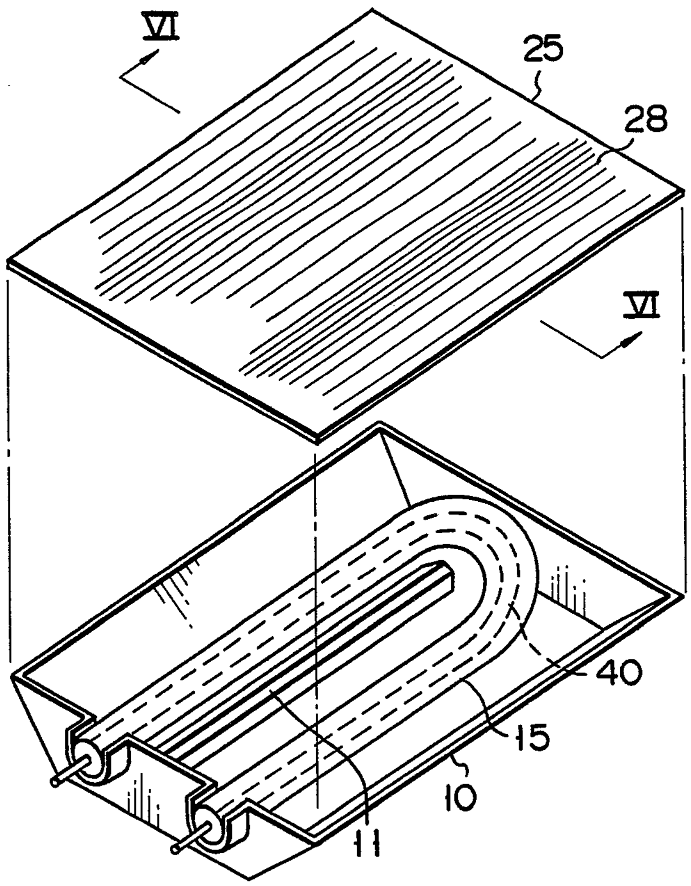


FIG. 5

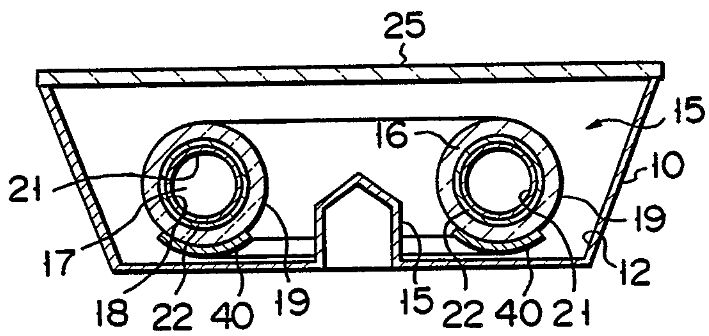


FIG. 6

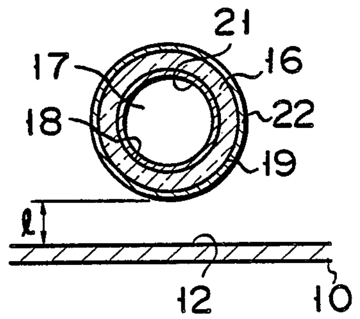


FIG. 7

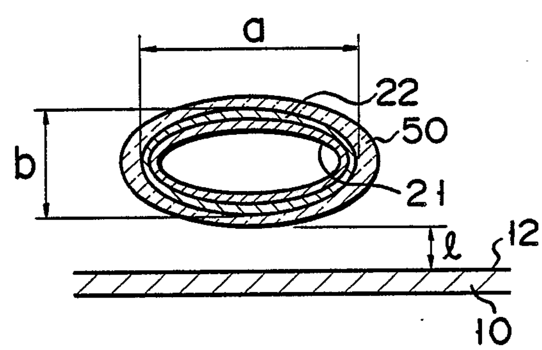


FIG. 8

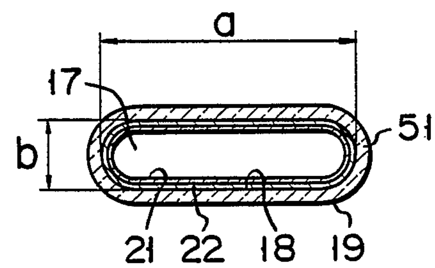
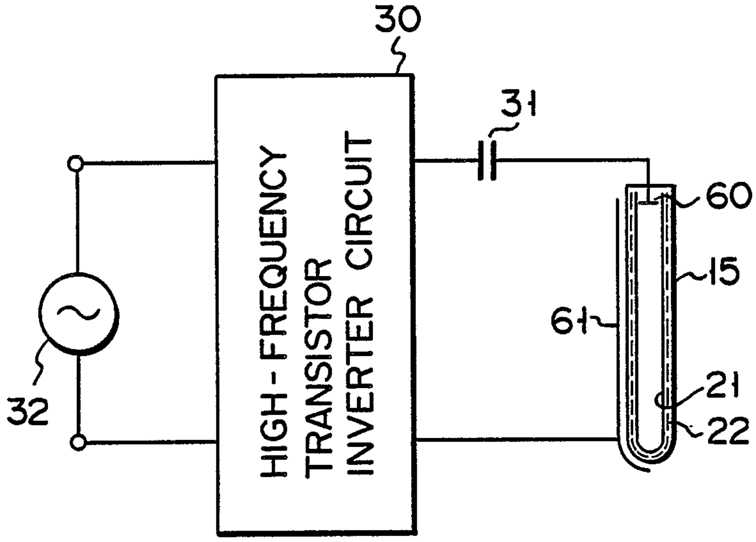


FIG. 9


30
31
60
15
61
21
22
32
HIGH-FREQUENCY
TRANSISTOR
INVERTER CIRCUIT

F I G. 10