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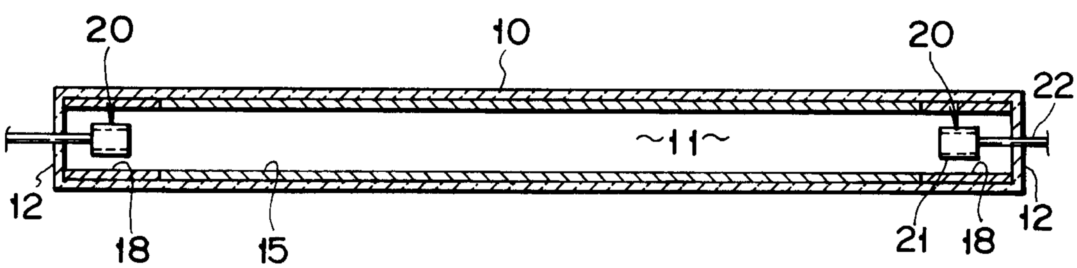
(71) Applicant: **TOSHIBA LIGHTING & TECHNOLOGY CORPORATION**
4-28, Mita 1-chome
Minato-ku Tokyo(JP)

(72) Inventor: **Takagi, Masami**
4-9-202, Shinmachi
Kanagawa-ku, Yokohama-shi(JP)
Inventor: **Tsutsui, Naoki**
4-7-3-205, Nishikojiya
Oota-ku, Tokyo(JP)
Inventor: **Asakura, Masahiko**
7-10-18, Hirasaku
Yokosuka-shi, Kanagawa-ken(JP)
Inventor: **Ishizuka, Masahiro**
5-18-8, Togoshi
Shinagawa-ku, Tokyo(JP)

(74) Representative: **Henkel, Feiler, Hänzel & Partner**
Möhlstrasse 37
W-8000 München 80(DE)

(54) **Cold cathode discharge lamp.**

(57) A cold cathode discharge lamp includes phosphor films (15) formed on the inner surface of a bulb (1), discharge gas sealed in the bulb and containing at least xenon, and a pair of cold cathode and electrodes (20, 30) provided in the bulb for making the discharge gas cause discharge, and Exo electron emitting layer made of α-alumina (18) is installed in the bulb, which emits Exo electrons into the bulb by the stimulus energy equal to or less than the work function in the dark.



F I G. 1

EP 0 466 138 A1

The present invention relates to a cold cathode discharge lamp with a phosphor film formed inside the bulb, particularly relates to a cold cathode xenon discharge lamp.

For various types of discharge lamps, in general, ionization is not smoothly executed unless initial electrons triggering discharge for startup are present and, consequently, startup is impossible or difficult.

The initial electrons triggering discharge include thermoelectrons, photoelectrons, electrons emitted by a high electric field, and cosmic rays in the nature. When a discharge lamp is left in dark atmosphere where no external light reaches, startup is difficult because cosmic rays are present as initial electrons since no photoelectron is present. When the lamp is used in completely-shielded housing or casing, startup by photoelectrons cannot be expected because light in the nature may hardly reach. Moreover, for startup by thermoelectrons, a heating-type electrode with a complicated structure is necessary because thermoelectrons are supplied by heating the electrode with thermoelectron emitting material.

Especially for a lamp using a cold cathode for the electrode, the starting characteristic in the dark is inferior because the cold cathode does not emit thermoelectrons for startup.

In addition, when discharge gas containing xenon is sealed in the bulb, that is, for the cold cathode xenon discharge lamp, discharge hardly occurs because xenon has inferior ionisation characteristic, the starting voltage rises, and it takes time for startup.

That is, the cold cathode xenon discharge lamp has a disadvantage that the starting characteristic of the lamp in the dark is inferior.

To improve the starting characteristic of the above cold cathode xenon discharge lamp, a means has been adopted so far to use electrons emitted from the radioisotope (RI) such as ^{63}Ni or ^{147}Pm applied to the electrode or to emit initial electrons by applying external light to the electrode coated with CaO. (Japanese Patent Publication No. 34220 of 1985)

However, to handle the electrode provided with a radioisotope, special care is necessary and the radioisotope should be sealed in the electrode in the form of a sealed radioactive source. Therefore, the manufacturing cost relatively increases.

Meanwhile, CaO does not preferably function in the complete dark because it does not emit electrons unless there is external light. Therefore, it is inferior in reliability.

It is an object of the present invention to provide a cold cathode xenon discharge lamp which can easily be handled and always emits initial electrons for triggering discharge, so that starting characteristic is improved.

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 sectional view of a cold cathode xenon discharge lamp according to the first embodiment of the present invention;

Fig. 2 is a sectional view of a cold cathode xenon discharge lamp according to a modification of the first embodiment;

Fig. 3 is a sectional view of a cold cathode xenon discharge lamp according to the second embodiment of the present invention;

Fig. 4 is a sectional view of a cold cathode xenon discharge lamp according to the third embodiment of the present invention;

Fig. 5 is a sectional view of a cold cathode xenon discharge lamp according to the fourth embodiment of the present invention;

Figs. 6 and 7 are sectional views of cold cathode xenon discharge lamps according to modifications of the fourth embodiment, respectively;

Fig. 8 is a fragmentary sectional view of a cold cathode xenon discharge lamp according to a modification of the fourth embodiment;

Fig. 9 is a sectional view of a cold cathode xenon discharge lamp according to the fifth embodiment of the present invention;

Fig. 10 is an enlarged sectional view of the electrode portion of the fifth embodiment;

Figs. 11 and 12 are enlarged sectional views of modifications of the electrode portions of the fifth embodiment respectively;

Figs. 13 through 15 are sectional views of cold cathode xenon discharge lamps according to the sixth through eighth embodiments of the present invention; and

Fig. 16 is a diagram showing the results of measuring the discharge starting duration of the cold cathode xenon discharge lamps of the embodiments of the present invention and that of the existing cold cathode xenon discharge lamps.

The present invention is described below according to the first embodiment shown in Fig. 1.

Fig. 1 is a sectional view of the cold cathode xenon discharge lamp used for the back light of an liquid crystal display (LCD), in which numeral 10 represents a glass bulb.

The bulb 10 in this embodiment is made of a straight tube having approximately circular cross section with the outside diameter of 6.5 mm, the inside diameter of 5.0 mm, and the overall length of, for example, 270 mm, in which a discharge space 11 is specified.

The both ends of the bulb 10 is sealed by a button stem 12. Two electrodes 20 is installed on these stems 12 respectively. The electrodes are separate by 250 mm from each other. The electrode 20 is a cold cathode which includes an electrode body 21 made by forming a nickel plate into a cylinder and a lead wire 22 connected to the electrode body 21. The lead wire 22 passes through the button stem 12 with it kept airtight and is led to the outside.

The above discharge space 11 of the bulb 10 is filled with discharge gas consisting of 100% xenon gas at the pressure of 100 Torr. Mixture gas between xenon and noble gas such as argon or neon may be used for the discharge gas instead of 100% xenon gas.

The inner surface of the bulb 10 exposed to the discharge space 11 is coated with a phosphor film 15 excluding the both ends or portions close to electrodes. The phosphor film 15 is made of cerium-terbium activation aluminate phosphor emitting green light with the peak wavelength of approx. 540 nm. The phosphor is not restricted to the above substance. It is also possible to use a general three-band phosphor made by mixing three phosphors having luminous areas of blue, green, and red respectively.

At the end of the above bulb 10, a layer 18 made of a substance emitting electrons is formed closely to the electrode 20. The electron emitting substance referred in this specification means a substance which emits electrons by the stimulus energy equal to or less than the work function in the dark. Such stimulus energy may be a thermal energy of for example, a soon temperature of 25 °C. The electron emitting substance layer 18 is made of translucent metallic oxide such as α-alumina, γ-alumina ($A\ell_2O_3$), magnesia (MgO), zinc oxide (ZnO), and lead oxide (PbO). This embodiment uses a layer made of α-alumina powder for the electron emitting substance layer 18 because it is stable in the electron emitting characteristic. Such an electron emitting substance is known in BRITISH JOURNAL OF APPLIED PHYSICS, Vol. 9, March 1958, "A survey of exo-electron emission phenomena".

The above electron emitting substance layer 18 made of alumina can be formed by, for example, mixing butyl acetate with fine-grain alumina and cotton bromide to make suspension, applying the suspension around the electrodes on the inner surface of the bulb 10, and baking it to form ceramic.

For other method, an alumina film can be formed by applying organic compound aluminum solution (e.g. alkoxide aluminum solution) to the inner surface of the bulb 10 and drying it before baking to form it as an alumina film.

It is also possible to apply aluminum alone not in the form of aluminum oxide to the inner surface of the bulb 10 and oxidize the aluminum through heating in the bulb-sealing and exhaust processes.

The above electron emitting substance layer 18 is directly exposed to the discharge space 11, that is, it is not covered with the phosphor film 15. In more detail, for this embodiment, the phosphor film 15 formed in the inner surface of the bulb 10 is not extended up to the portion close to the electrode 20 but the electron emitting substance layer 18 is formed at the portion free from the phosphor film.

The above cold cathode xenon discharge lamp is turned on at the high frequency of 50 KHz through a high-frequency transistor inverter (not illustrated).

The cold cathode xenon discharge lamp having the above configuration is easily started in the dark and the starting duration is greatly decreased.

In other words, the electron emitting substance layer 18 formed on the inner surface of the bulb 10 or the alumina film always emits electrons by receiving thermal energy from peripheral atmosphere without being provided with a high electric field even in the dark at the ordinary temperature.

Therefore, because the electron triggers discharge, the cold cathode xenon discharge lamp is quickly turned on in a space interrupted from cosmic rays in the dark.

Moreover, because the electron emitting substance layer 18 is not covered with the phosphor film 15, the electrons are emitted to the discharge space at a high probability and discharge breakdown is prompted. That is, because the electron is a low-speed electron, the probability for the electrons to be emitted to the discharge space decreases because it is absorbed by the phosphor film 15 when the electron emitting substance layer 18 is covered with the phosphor film 15 and lighting may be delayed though it is not so late as the prior art. In addition, the insulating property of the phosphor film 15 depends on the grain size, grain size distribution, and relative contact electrification amount of the phosphor composing the film. Therefore, when the electron emitting substance layer 18 is covered with the phosphor film 15, the number of electrons to be emitted from the electron emitting substance layer 18 depends on the type of the phosphor used.

For the above embodiment, because the electron emitting substance layer 18 is formed so that it will be exposed to the discharge space without covering it with the phosphor film 15, the number of electrons to be emitted to the discharge space increases and the probability to cause discharge breakdown increases.

By installing the above exposed electron emitting substance layer 18 at a portion close to the electrode 20, the illuminance distribution is not greatly affected because the area free from the phosphor film 15 is close to the electrode even if the phosphor film 15 is not formed at the portion. For the portion close to the electrode 20 where electric fields are concentrated, the electron emitted from the layer 18 is accelerated by the electric field of high intensity, so that preferable discharge breakdown is prompted, and startup is securely executed. For the above embodiment, the electron emitting substance layer 18 is formed so that it will face the electrode 20 installed at the both ends of the bulb 10 respectively. However, as shown in Fig. 2, it is also possible to form the electron emitting substance layer 18 only on one of the electrodes 20.

Other embodiments are described below according to the drawings corresponding to each of them. For these embodiments, the description of portions and elements substantially same as those of the above embodiment is omitted by giving the same symbols to them. For the embodiment in Fig. 1, the electron emitting substance layer 18 has a structure independent of the phosphor film 15. However, as the second embodiment shown in Fig. 3, it is possible to laminate the electron emitting substance layer 18 on the inner surface of the phosphor film 15. In this case, the electron emitting substance layer 18 can be installed only on one of the electrodes 20.

For the above embodiment, the electron emitting substance layer 18 is formed so that it will be exposed inside the bulb 10. However, as the third embodiment shown in Fig. 4, it is possible to form the electron emitting substance layer 18 under the phosphor film 15 or between the phosphor film 15 and the inner surface of the bulb 10. For this embodiment, the electron emitting substance layer 18 is formed so that it will have the dimension approximately same the phosphor film 15. However, it is also possible to form the electron emitting substance layer 18 only at a portion close to at least one electrode.

For Fig. 1, the case is described in which an internal electrodes are sealed in the both ends of the bulb 10 respectively. For the present invention, however, it is also possible to configure either electrode as an external electrode. Fig. 5 shows this embodiment. This fourth embodiment uses a bulb 10 with the overall length of 70 mm, the outside diameter of 2.5 mm, and the inside diameter of 1.4 mm, in which a cold cathode 20 consisting of a nickel cylinder with the overall length of 2.5 mm and the outside diameter of 0.7 mm is installed on one end of the bulb and an external electrode 30 extending in the bulb axis direction in the form of a belt is installed on the outer surface of the bulb 10. The electron emitting substance layer 18 is formed as a ring on the inner surface of the bulb 10 close to the internal electrode 20. The phosphor film 15 formed on the inner surface of the bulb 10 is made of lanthanum phosphate, which emits umber light. Discharge gas consisting of 100% xenon gas is sealed in the bulb 10 at the pressure of 100 Torr. The lamp having the above configuration is suitable for meter pointers.

The above cold cathode xenon discharge lamp starts within a very short time even in the dark because the electron emitting substance layer 18 not covered with the phosphor film 15 is formed in the inner surface of the bulb 10 so that it will face the cold cathode 20.

For the fourth embodiment, the electron emitting substance layer 18 is formed closely to the internal electrode 20. However, as shown in Fig. 6, it is possible to form the electron emitting substance layer 18 separately from the internal electrode. For this embodiment, though the electron emitting substance layer 18 is formed on the surface of the phosphor film 15, it is also possible to form it directly on the end of the bulb 10.

As shown in Fig. 7, it is also possible to form the electron emitting substance layer 18 under the phosphor film 15 or between the phosphor film 15 and the inner surface of the bulb 10. For this embodiment, though the electron emitting substance layer 18 is formed so that it will have the dimension approximately same as the phosphor film 15, it can also be formed only at a portion close to at least one electrode.

As shown in Fig. 8, the electron emitting substance layer 18 can be covered with a metallic thin layer 40. The structure of the metallic layer 40 is not restricted to that shown in Fig. 8. Any type of structure can be applied as long as the electron emitting substance layer 18 is exposed.

For the above embodiments, the electron emitting substance layer 18 is installed on the bulb 10 side, that is, it is secured to the bulb. However, the bulb 10 can be installed on the electrode side. This embodiment is shown below.

The cold cathode discharge lamp shown in Fig. 9 is the same as that shown in Fig. 3 except the fact that the electron emitting substance layer 18 is formed on the electrode 20. Therefore, description is made for the electrode 20. The electrode body 21 of the electrode 20 is filled with an electron emitting substance 23 made of lanthanum boride LaB_6 together with nickel. That is, the electrode body 21 is made by filling it with mixture of nickel powder and LaB_6 power of 10 to 20 capacity percent and cold-forming and swagging it before heat-treating it to melt the nickel powder and deposit LaB_6. Thus, the electron emitting substance 23 made of LaB_6 is held by the electrode body 21. The electron emitting substance 23 emits electrons by the stimulus energy equal to or more than the work function, which is used to induce discharge when the starting voltage is applied and different from the substance forming the electron emitting substance layer 18.

A layer 18 made of an electron emitting substance (e.g. α-alumina) is formed on the outer surface of the electrode 20. The electron emitting substance layer 18 made of the alumina can be formed by, for example, mixing butyl acetate with fine-grain alumina and cotton bromide to make suspension, applying the suspension to the outer surface of the electrode 20, and baking it to form ceramic.

For other method, an alumina film can be formed by applying organic compound aluminum solution (e.g. alkoxide aluminum solution) to the inner surface of the bulb 10 and drying it before baking to form it as an alumina film.

It is also possible to apply aluminum alone not in the form of aluminum oxide to the outer surface of the electrode 20 and oxidize the aluminum through heating in the bulb-sealing and exhaust processes.

The cold cathode xenon discharge lamp with the above configuration, like the above embodiment, easily starts in the dark and the starting duration can greatly be decreased.

That is, the electron emitted from the electron emitting substance layer 18 formed on the outer surface of the electrode 20 triggers discharge and the cold cathode xenon discharge lamp is quickly turned on in a dark space interrupted from cosmic rays.

Because the electron emitting substance layer 18 is installed on the electrode 20, the electrons emitted from the electron emitting substance layer 18 securely reach the discharge space and effectively work for discharge breakdown without being absorbed in the tube wall and, thus, many electrons contribute to start of discharge. Therefore, stable startup is possible.

For the embodiments shown in Figs. 9 and 10, the electron emitting substance layer 18 is applied to the outer surface of the electrode body 21 of the electrode 20. However, it is also possible to fill the electrode body 21 with the electron emitting substance 18 instead of the electron emitting substance 23 to emit electrons with the stimulus energy equal to or more than the work function.

It is also possible to form the electron emitting substance layer 18 on the inner surface of the electrode body 21 to reserve a vacancy inside the electron emitting substance layer 18.

Moreover, it is possible to form the electron emitting substance layer 18 only on either electrode 20. For Fig. 9, the case is described in which an internal electrodes are installed at the both ends of the bulb 10 respectively. However, the present invention is not restricted to the case. As shown in Fig. 13, either electrode can be an external electrode similarly to the embodiment shown in Fig. 5.

For the above embodiment, the layer 18 is formed in the bulb 10 by the electron emitting substance. For the present invention, however, the electron emitting substance may be formed in the bulb 10 by any means. For example, as shown in Fig. 14, it is possible to form the phosphor electron emitting substance layer 50 made of mixture of phosphor and electron emitting substance on the inner surface of the bulb 10. In this case, the mixture layer 50 serves as a phosphor film and electron emitting substance layer.

The idea of the present invention can also be applied to the discharge lamp with electrodes installed outside as shown in Fig. 15. For the embodiment shown in Fig. 15, a pair of stripped external electrodes 30 are installed on the outer surface of the bulb 10 so that they will face each other. In this case, it is recommended to form a pair of electron emitting substance layers 18 on the bulb 10 directly or on the surface of the phosphor film 15 as shown in figure. For the above embodiment, the following three ideas are embodied: the idea to install the layer made by electron emitting substance at the bulb side, the idea to install it at the electrode side, and the idea to mix the electron emitting substance in the phosphor film.

However, it is also possible to realize an embodiment by combining at least two of the three ideas. Fig. 16 shows the result of measuring the delay of the discharge starting time of typical embodiments among the above embodiments and that of a sample according to the prior art using no electron emitting substance. In Fig. 16, the abscissa shows the discharge start delay time (Sec) and the ordinate shows the cumulative discharge starting rate. The following five types of samples are used: 100 samples 1 made by forming the electron emitting substance layer (α-alumina layer) 18 closely to electrodes as shown in Fig. 1, 100 samples 2 made by filling the electron emitting substance 18 in the electrode as shown in Fig. 11, 100 samples 3 made by mixing electron emitting substance (α-alumina) with phosphor as shown in Fig. 14, 100 samples 4 made by forming the electron emitting substance layer (γ-alumina layer) 18 between the inner surface of the bulb and the phosphor film as shown in Fig. 4, and 100 samples 5 according to the prior art. The phosphor film of every sample is formed by yttrium oxide. These manufactured samples are aged for a certain time. Then they are left in a bright place (1,000ℓx) for 12 hr and a dark place (0ℓx) for 12 hr. This operation is repeated seven times, so that they are left as they are for 168 hr then, the 1.2 kV sinusoidal wave (35 KHz) is applied to them in a dark place of 25°C. In this case, the time until the lamp current flows is measured. As the result of the measurement, it is found that the sample 1 is the most preferable because it has the shortest discharge start delay time. However, it is also found that the samples 2 through 4 are preferable compared with the sample 5 according to the prior art. The profile of the above bulb can be circular, elliptic, or flat oval and the bulb shape can be not only straight but U-type.

The present invention is applied to the lamp with a cold cathode inside the bulb. As previously mentioned, the cold cathode lamp has an inferior starting characteristic in the dark because it does not have the structure in which the cold cathode emits thermoelectrons at start. Moreover, when xenon is sealed in the bulb, that is, for a cold cathode xenon discharge lamp, ionization hardly occurs, the starting voltage rises, and it takes time for startup because the ionization characteristic of xenon is inferior.

Therefore, it is clarified that the present invention is effective for the above cold cathode xenon discharge lamp.

Claims

1. A cold cathode discharge lamp comprising:
a bulb (1) having a discharge space (11) therein; phosphor films (15, 50) formed on the inner surface side of said bulb;
discharge gas sealed in said discharge space of the bulb and containing at least xenon; and
cold cathode electrodes (20, 30) for making said discharge gas cause discharge, and characterized by comprising:
electron emitting means (18, 50) installed in said bulb and emitting electrons into said discharge space of the bulb by the stimulus energy equal to or less than the work function in the dark.

2. A cold cathode discharge lamp according to claim 1, characterized in that said electron emitting means is exposed in said discharge space of the bulb to directly emit electrons into the discharge space bulb.

3. A cold cathode discharge lamp according to claim 2, characterized in that said electron emitting means is mixed in said phosphor film.

4. A cold cathode discharge lamp according to claim 2, characterized in that said electron emitting means is formed by an electron emitting substance and has a fixed layer in said bulb.

5. A cold cathode discharge lamp according to claim 4, characterized in that said electron emitting substance layer is installed closely to at least one of said cold cathode electrodes (20, 30).

6. A cold cathode discharge lamp according to claim 4, characterized in that said cold cathode electrodes (20, 30) are separately installed in said bulb at a certain interval and said electron emitting substance layer is secured to the bulb portion close to at least one electrode.

7. A cold cathode discharge lamp according to claim 4, 5 or 6, characterized in that said electrode (20) has a cylindrical body, and said electron emitting substance layer is secured in the body.

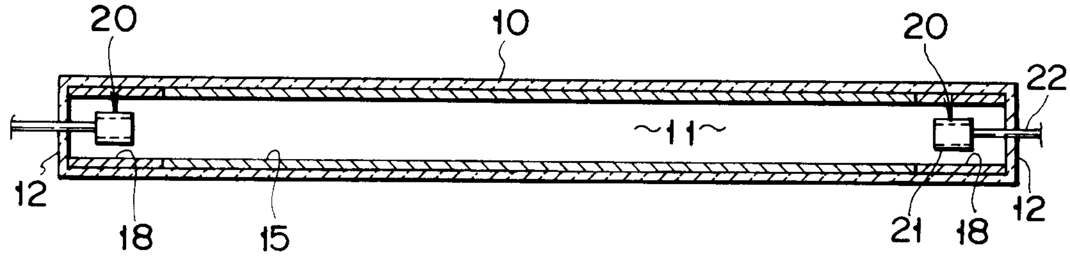
8. A cold cathode discharge lamp according to claim 4, 5 or 6, characterized in that said electrode (20) has a cylindrical body, and said electron emitting substance layer is secured to the outer surface of the cylindrical body and has electron emitting means for emitting electrons by receiving stimulus energy equal to or more than the work function.

9. A cold cathode discharge lamp according to claim 4, characterized in that at least one of said electrodes (20, 30) is installed outside said bulb and said electron emitting substance layer is secured to the bulb so that it will face the electrode.

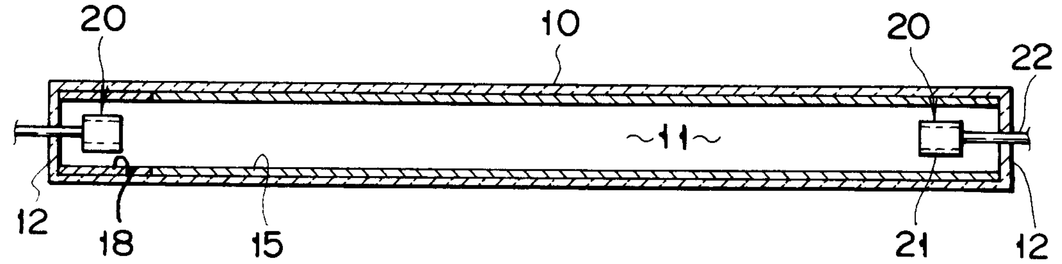
10. A cold cathode discharge lamp according to any one of preceding claims, characterized in that said electron emitting means is formed by at least one of alumina, magnesium oxide, zinc oxide, and lead monoxide.

11. A cold cathode discharge lamp comprising:
a bulb difining a discharge space;
a phosphor film formed side of said bulb;
a rare gas containing at least xenon as a discharge gas sealed in said discharge space of the bulb;
cold cathode electrodes for making said discharge gas generate discharge; and
metal oxide material installed in said bulb.

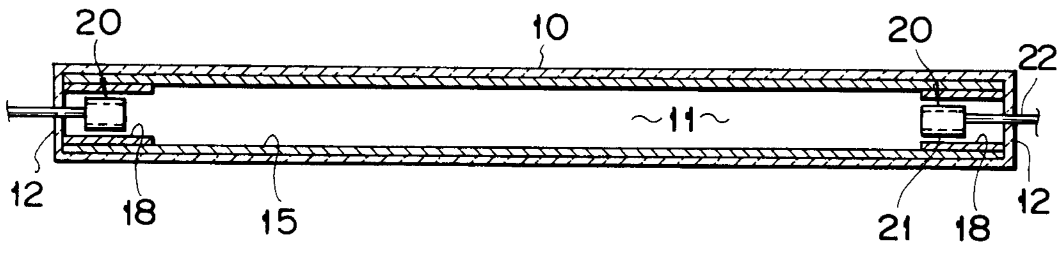
12. A cold cathode discharge lamp according to claim 11, wherein said metal oxide material is made of at least one of alumina, magnesium, oxide, zinc oxide and lead oxide.



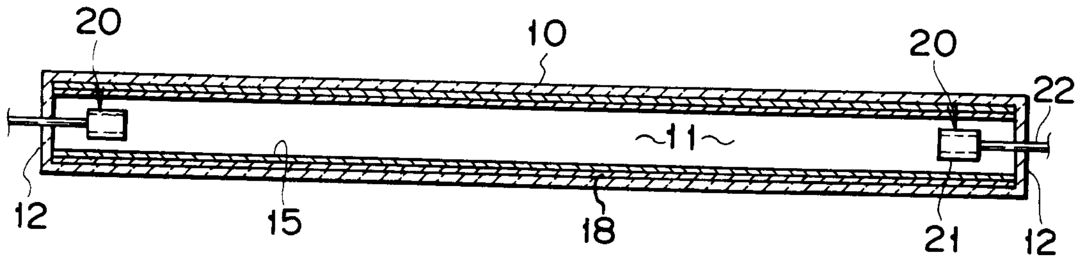
F I G. 1



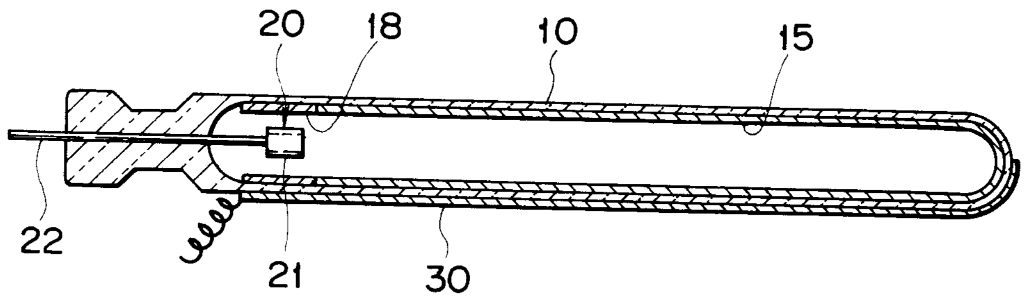
F I G. 2



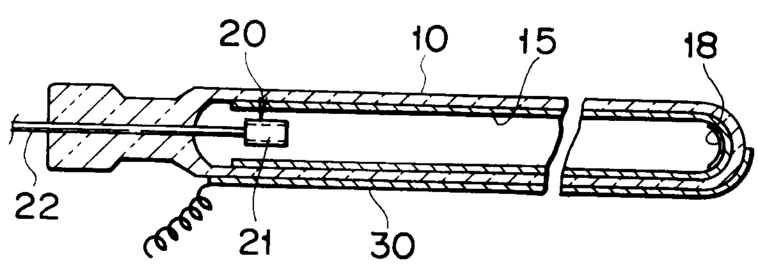
F I G. 3



F I G. 4



F I G. 5



F I G. 6

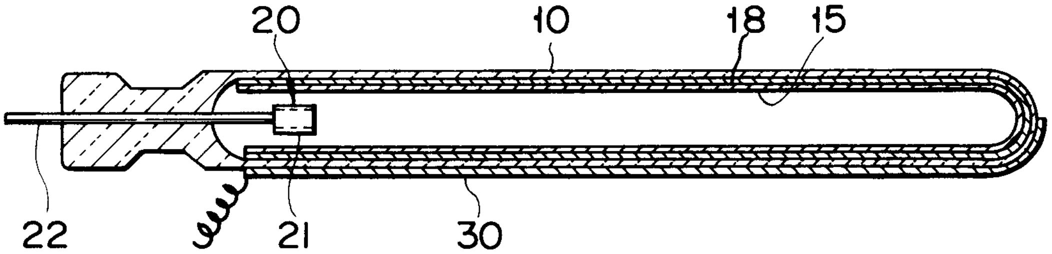


FIG. 7

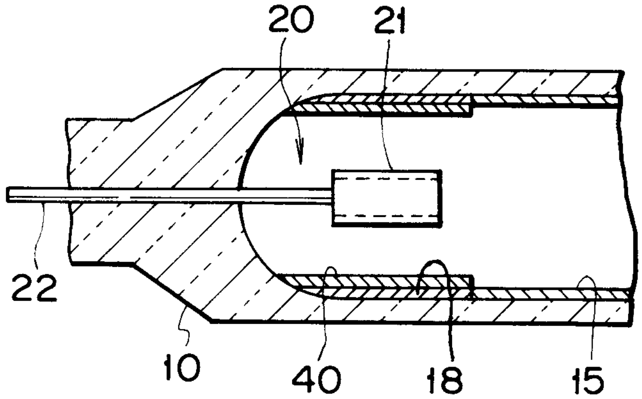


FIG. 8

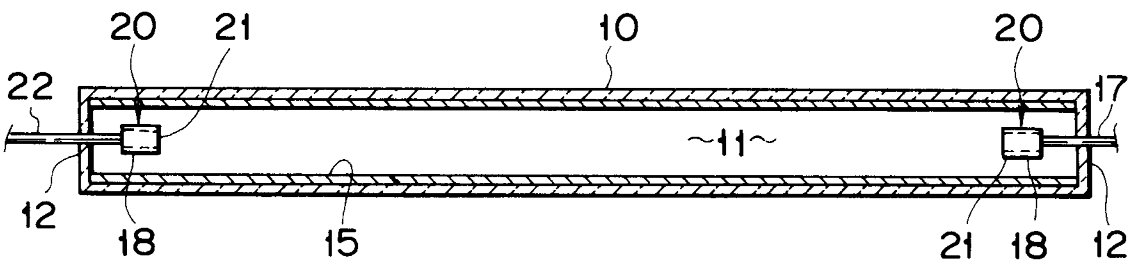


FIG. 9

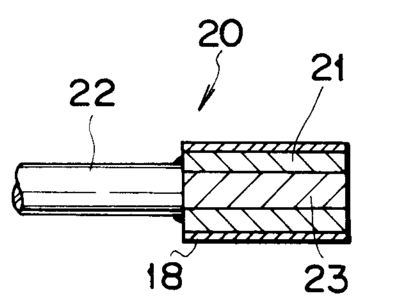


FIG. 10

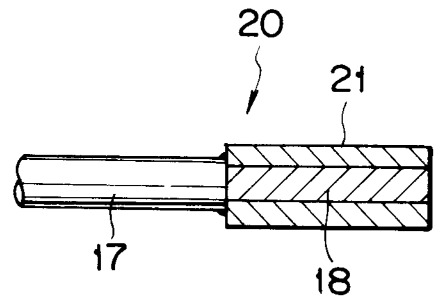


FIG. 11

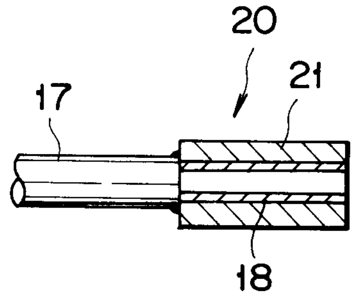


FIG. 12

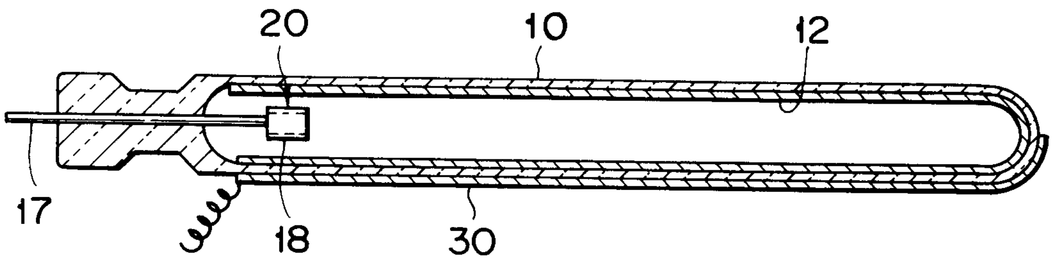


FIG. 13

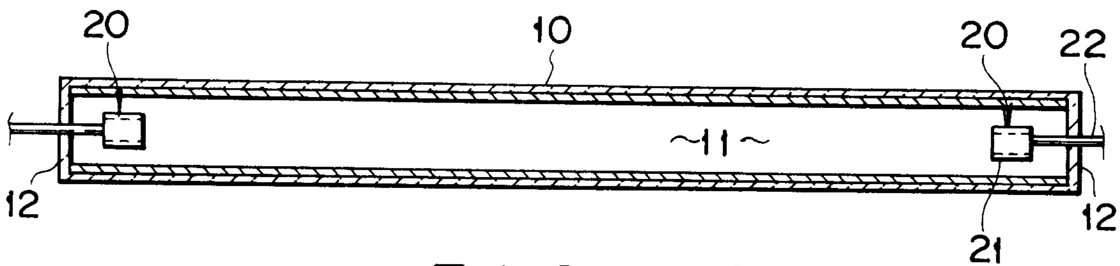


FIG. 14

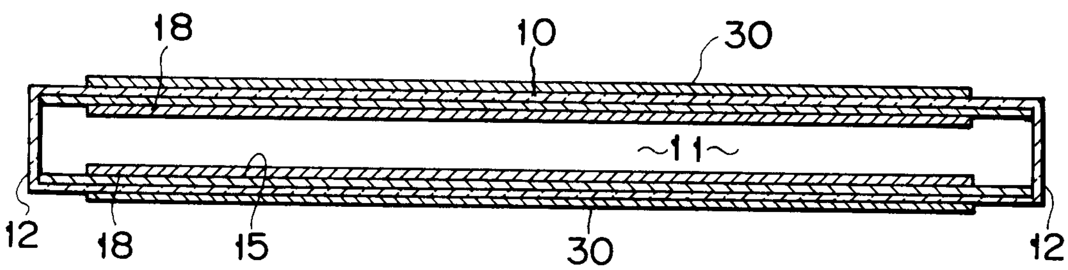


FIG. 15

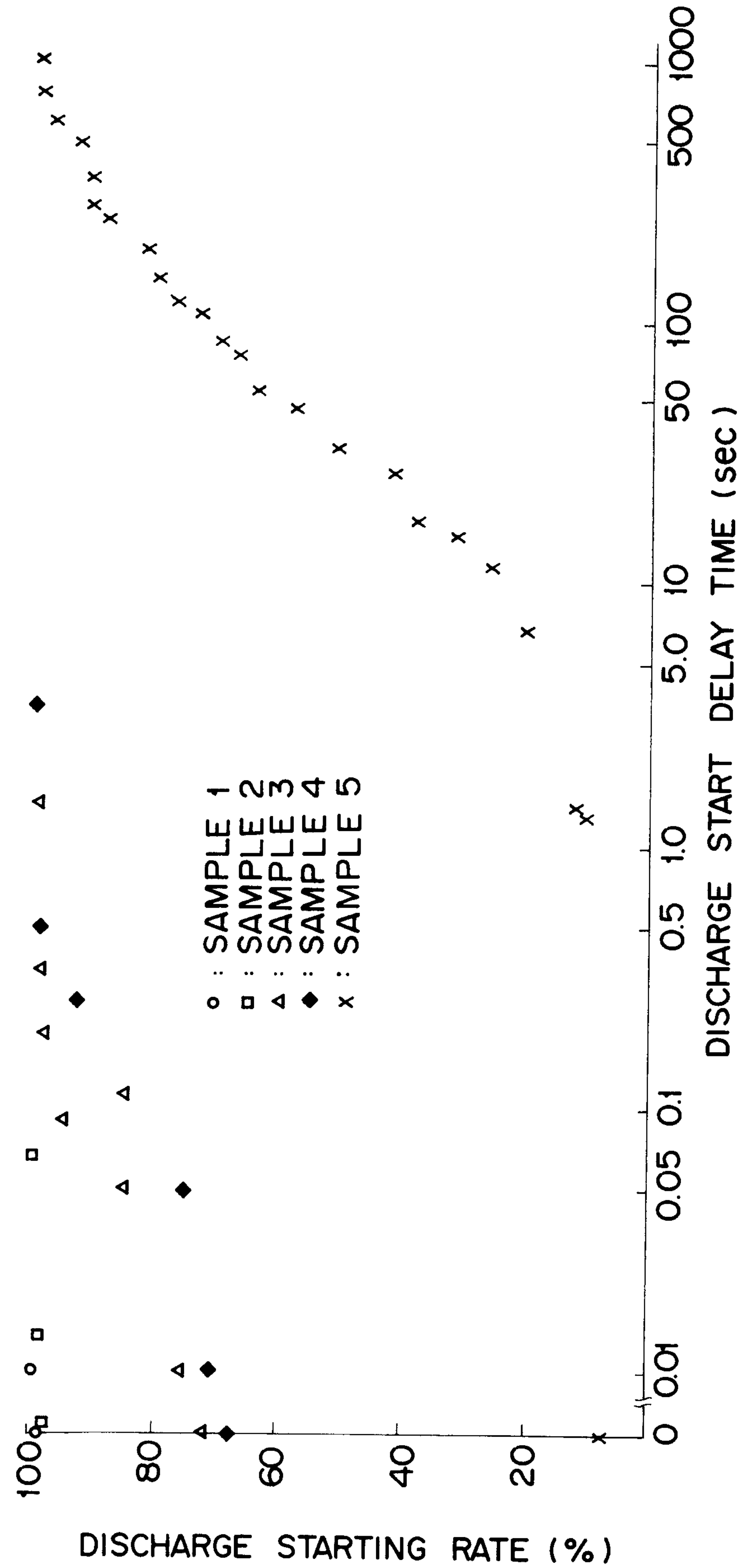

DISCHARGE STARTING RATE (%)
100
80
60
40
20
0
0.01
0.05
0.1
0.5
1.0
5.0
10
50
100
500
1000
DISCHARGE START DELAY TIME (sec)
○ : SAMPLE 1
□ : SAMPLE 2
△ : SAMPLE 3
◆ : SAMPLE 4
× : SAMPLE 5

FIG. 16

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91111508.7

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X;Y	EP - A2 - 0 348 979 (TOSHIBA LIGHTING) * Column 4, line 48 - column 5, line 27; column 10, lines 22-39; fig. 2,3,10 * --	1,2, 4-6, 9-12; 3,7,8	H 01 J 61/78
Y	US - A - 4 887 002 (DOBASHI et al.) * Column 3, lines 9-46; fig. 1,3,7-10 * --	7,8	
Y	US - A - 4 914 723 (ELLERBECK et al.) * Abstract * ----	3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H 01 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	15-10-1991	KUTZELNIGG

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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EPO FORM 1503 03.82 (P0401)