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(71) Applicant *(for all designated States except US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **DEKKER, Jan, P.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: **ROLFES, Johannes, G., A.**; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

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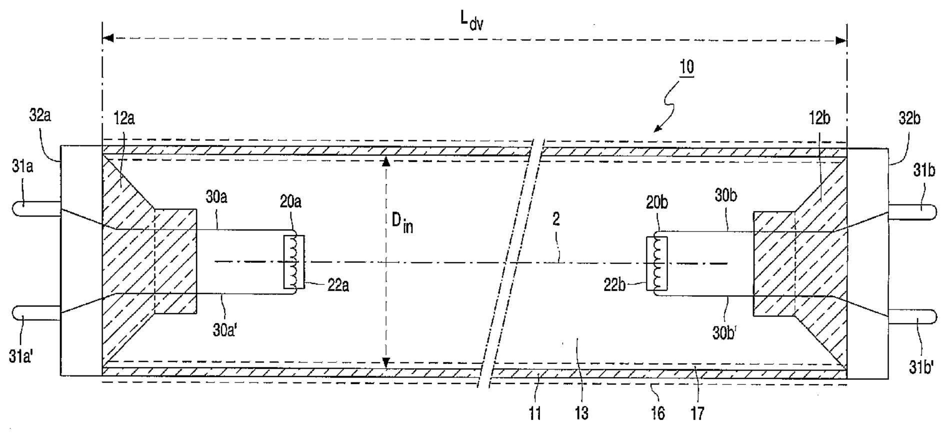
[Continued on next page]

(54) **Title:** LOW-PRESSURE MERCURY VAPOR DISCHARGE LAMP



$$\frac{m_{Hg}}{D_{in} \times L_{dv}} = C \qquad \text{(I)}$$

(57) **Abstract:** Low-pressure mercury vapor discharge lamp has an at least partly substantially cylindrical discharge vessel (10) with a length L_{dv} and with an internal diameter D_{in}. The discharge vessel encloses, in a gastight manner, a discharge space (13) provided with a inert gas mixture and with mercury. The discharge vessel comprises discharge means (electrodes 20a; 20b) for maintaining a discharge in the discharge space. A conductive layer (16) is disposed surrounding at least partially the discharge in the discharge space. The conductive layer is provided with potential means for applying a potential to the conductive layer. The ratio of the weight of mercury mxg in the discharge vessel to the product of the internal diameter D_{in} and the length of the discharge vessel L_{dv} is given by the relation: Formula (I), wherein $C \leq 0.01$ µg/mm$^{2.}$ The discharge lamp according to the invention operates under unsaturated mercury conditions.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Low-pressure mercury vapor discharge lamp

The invention relates to a low-pressure mercury vapor discharge lamp.

The invention also relates to a compact fluorescent lamp.

In mercury vapor discharge lamps, mercury constitutes the primary component for the (efficient) generation of ultraviolet (UV) light. A luminescent layer comprising a luminescent material (for example, a fluorescent powder) may be present on an inner wall of the discharge vessel to convert UV to other wavelengths, for example, to UV-B and UV-A for tanning purposes (sun panel lamps) or to visible radiation for general illumination purposes. Such discharge lamps are therefore also referred to as fluorescent lamps. Alternatively, the ultraviolet light generated may be used for germicidal purposes (UV-C). The discharge vessels of low-pressure mercury vapor discharge lamps are usually circular and comprise both elongate and compact embodiments. Generally, the tubular discharge vessel of a compact fluorescent lamp comprises a collection of comparatively short straight parts having a comparatively small diameter, which straight parts are connected together by means of bridge parts or via bent parts. Compact fluorescent lamps are usually provided with an (integrated) lamp cap. Normally, the means for maintaining a discharge in the discharge space are electrodes arranged in the discharge space. In an alternative embodiment the low-pressure mercury vapor discharge lamp comprises a so-called electrodeless low-pressure mercury vapor discharge lamp.

In the description and claims of the current invention, the designation “nominal operation” is used to refer to operating conditions where the mercury vapor pressure is such that the radiation output of the lamp is at least 80% of that when the light output is a maximum, i.e. under operating conditions where the mercury vapor pressure is an optimum. In addition, in the description and claims, the “initial radiation output” is defined as the radiation output of the discharge lamp 1 second after switching-on of the discharge lamp, and the “run-up time” is defined as the time needed by the discharge lamp to reach a radiation output of 80% of that during optimum operation.

Low-pressure mercury vapor discharge lamps are known comprising an amalgam. Such discharge lamps have a comparatively low mercury vapor pressure at room temperature. As a result, amalgam-containing discharge lamps have the disadvantage that the initial radiation output is also comparatively low when a customary power supply is used to operate said lamp. In addition, the run-up time is comparatively long because the mercury vapor pressure increases only slowly after switching on the lamp.

Apart from amalgam-containing discharge lamps, low-pressure mercury vapor discharge lamps are known which comprise both a (main) amalgam and a so-called auxiliary amalgam. If the auxiliary amalgam comprises sufficient mercury, then the lamp has a comparatively short run-up time. Immediately after the lamp has been switched on, i.e. during preheating of the electrodes, the auxiliary amalgam is heated by the electrode so that it comparatively rapidly dispenses a substantial proportion of the mercury that it contains. In this respect, it is desirable that, prior to being switched on, the lamp has been idle for a sufficiently long time to allow the auxiliary amalgam to take up sufficient mercury. If the lamp has been idle for a comparatively short period of time, the reduction of the run-up time is only small. In addition, in that case the initial radiation output is (even) lower than that of a lamp comprising only a main amalgam, which can be attributed to the fact that a comparatively low mercury vapor pressure is adjusted in the discharge space by the auxiliary amalgam. An additional problem encountered with comparatively long lamps is that it takes comparatively much time for the mercury liberated by the auxiliary amalgam to spread throughout the discharge vessel, so that after switching-on of such lamps, they demonstrate a comparatively bright zone near the auxiliary amalgam and a comparatively dark zone at a greater distance from the auxiliary amalgam, which zones disappear after a few minutes.

In addition, low-pressure mercury vapor discharge lamps are known which are not provided with an amalgam and contain only free mercury. These lamps also referred to as mercury discharge lamps, have the advantage that the mercury vapor pressure at room temperature and hence the initial radiation output are comparatively high as compared with amalgam-containing discharge lamps and as compared to discharge lamps comprising a (main) amalgam and an auxiliary amalgam. In addition, the run-up time is comparatively short. After having been switched on, comparatively long lamps of this type also exhibit a substantially constant brightness over substantially the whole length, which may be attributed to the fact that the vapor pressure (at room temperature) is sufficiently high at the time of switching-on of these lamps.

A comparatively large amount of mercury is necessary for the low-pressure mercury vapor discharge lamps known in the art in order to realize a sufficiently long lifetime. A drawback of the known discharge lamps is that they form a burden on the environment. This is in particular the case if the discharge lamps are injudiciously processed after the end of the lifetime.

The invention has for its object to eliminate the above disadvantage wholly or partly. According to the invention, a low-pressure mercury vapor discharge lamp of the kind mentioned in the opening paragraph for this purpose comprises:

- a discharge vessel with a length L_{dv} and with an internal diameter D_{in},
- the discharge vessel enclosing, in a gastight manner, a discharge space provided with a inert gas mixture and with mercury,
- the discharge vessel comprising discharge means for maintaining a discharge in the discharge space,
- a conductive layer being disposed, the conductive layer at least partially surrounding the discharge in the discharge space and being provided with potential means for applying a potential to the conductive layer,
- the ratio of the weight of mercury m_{Hg} in the discharge vessel and the product of the internal diameter D_{in} and the length of the discharge vessel L_{dv} being given by the relation:

$$\frac{m_{Hg}}{D_{in} \times L_{dv}} = C,$$

wherein $C \leq 0.01\ \mu g/mm^2$.

The advantage of the provision of a conductive layer is that the mercury losses in the vicinity of the (inner) wall of the discharge vessel are reduced. Not wishing to be held to any particular theory, it is believed that by maintaining, during operation of the low-pressure mercury vapor discharge lamp, a potential to the conductive layer, the migration of alkali metal ions from the glass to the inner surface of the discharge vessel is influenced. The reduction of the quantity of mercury available for the discharge in the discharge space is mainly caused by the exchange of the alkali metal (for example, Na and/or K) and Hg, and by the absorption of mercury by the surface of the discharge vessel facing the discharge space. During operation of the discharge lamp, mercury enters the wall of the discharge vessel, while the alkali metal oxide simultaneously leaves the wall of the discharge vessel. By applying a (negative) potential difference between the conductive layer and the discharge in the discharge vessel, the migration of alkali metal ions toward the inner surface of the discharge vessel is resisted.

In addition, a discharge vessel of a low-pressure mercury vapor discharge lamp according the invention, having a ratio of the weight (expressed in μg) of mercury and the product of the internal diameter (expressed in mm) and the length (expressed in mm) of the discharge vessel which is below 0.01 $\mu g/mm^2$, contains a comparatively low amount of mercury. The mercury content is considerably lower than what is normally provided in known low-pressure mercury vapor discharge lamps. Given the range of the constant $C \leq 0.01$ $\mu g/mm^2$, the low-pressure mercury vapor discharge lamp according to the invention operates for certain ambient temperatures as so-called "unsaturated" mercury vapor discharge lamp.

The above given relation shows that the amount of mercury m_{Hg} in the discharge lamp is proportional to the product of the internal diameter D_{in} and the length of the discharge vessel L_{dv}. Roughly speaking, the amount of mercury in the discharge lamp is proportional to the size of the internal surface of the discharge vessel. Experiments have shown that the formula can at least be applied to low-pressure mercury vapor discharge lamps with a diameter of the discharge vessel in a range from approximately 3.2 mm (1/8 inch) to approximately 38 mm (12/8 inch) and for (corresponding) lengths in a range from approximately 10 mm (1/3 foot) to approximately $27 \cdot 10^2$ mm (9 feet) of the discharge vessels.

In the description and claims of the current invention, the designations "unsaturated" or "unsaturated mercury conditions" are used to refer to a low-pressure mercury vapor discharge lamp in which the amount of mercury dosed into the discharge vessel (during manufacture) of the low-pressure mercury vapor discharge lamp is equal to or lower than the amount of mercury needed for a saturated mercury vapor pressure at nominal operation of the discharge lamp:

Operating a mercury vapor discharge lamp under unsaturated mercury conditions has a number of advantages. Generally speaking, the performance of unsaturated mercury discharge lamps (light output, efficacy, power consumption, etc.) is independent of the ambient temperature as long as the mercury pressure is unsaturated. This results in a constant light output which is independent on the burning position of the discharge lamp (base up versus base down, horizontally versus vertically). In practice, a higher light output of the unsaturated mercury vapor discharge lamp is obtained in the application. Unsaturated lamps combine a higher light output with an improved efficacy in applications at elevated temperatures with minimum mercury content. This results in ease of installation and in freedom of design for lighting and luminaire designers. An unsaturated mercury discharge lamp gives a comparatively high system efficacy in combination with a comparatively low Hg content. In addition, unsaturated lamps have improved lumen maintenance. Since the trends towards further miniaturization and towards more light output from one luminaire will continue the forthcoming years, it may be anticipated that problems with temperature in applications will occur more frequently in the future. With an unsaturated mercury vapor discharge lamp these problems are largely reduced. Unsaturated lamps combine minimum mercury content with an improved lumen per Watt luminous efficacy performance at elevated temperatures.

When the performance of unsaturated lamps is compared with that of so-called cold-spot or so-called amalgam low-pressure mercury vapor discharge lamps, the following advantages can be mentioned. In a "cold-spot" mercury discharge lamp, the mercury pressure is controlled by a so-called cold-spot temperature somewhere in the discharge vessel. In an amalgam mercury discharge lamp, the mercury pressure is controlled by means of an amalgam; in a number of such amalgam discharge lamps an auxiliary amalgam is additionally employed. The initial radiation output and the run-up time and ignition voltage of an unsaturated mercury discharge lamp are comparable to those of cold-spot lamps. Other properties such as size (no cold-spot area necessary in an unsaturated discharge lamp; e.g. by introducing long stems), life time, color temperature, color rendering index, and reliability are at the same level as in known mercury discharge lamps. The lumen maintenance of unsaturated lamps is expected to be better than that of the known compact fluorescent lamps (CFL) and fluorescent discharge lamps (TL). With unsaturated lamps miniaturization can be driven to its limits because thermal problems are minimized. This can result in a reduction of the total cost of ownership for new installation unsaturated mercury discharge lamps.

The measure according to the invention enables the manufacture of long-life low-pressure mercury vapor discharge lamps which operate under conditions of unsaturated mercury content. Such unsaturated mercury discharge lamps have the advantage that the burden on the environment is reduced.

A preferred embodiment of the low-pressure mercury vapor discharge lamp according to the invention is characterized in that the conductive layer is translucent. By providing a translucent conductive layer, the light output of the low-pressure mercury vapor discharge lamp is not influenced. Preferably, the conductive layer is transparent. In a very favorable embodiment of the discharge lamp according to the invention the conductive layer is tin oxide.

A preferred embodiment of the low-pressure mercury vapor discharge lamp according to the invention is characterized in that the conductive layer is provided on an outer surface of the discharge vessel.

A preferred embodiment of the low-pressure mercury vapor discharge lamp according to the invention is characterized in that the conductive layer is striped or forms a spiral. Preferably, the conductive layer extends in the form of stripes or in the form of a helix along the length of the discharge vessel.

Preferably, the constant C is in a range of $0.0005 \leq C \leq 0.005$ µg/mm^2. In this regime of C the upper limit of the mercury content in the discharge lamp is further reduced. In this preferred embodiment, the discharge lamp according to the invention operates as an unsaturated mercury vapor discharge lamp.

A preferred embodiment of the low-pressure mercury vapor discharge lamp according to the invention is characterized in that the discharge vessel contains less than approximately 0.1 mg mercury. There is a tendency in governmental regulations to prescribe a maximum amount of mercury present in a low-pressure mercury vapor discharge lamp that, if the discharge lamp comprises less than said prescribed amount, allows the user to dispose of the lamp without environmental restrictions. If a mercury discharge lamp contains less than 0.2 mg of mercury such requirements are largely fulfilled. Preferably, the discharge vessel contains less than or approximately 0.05 mg mercury ($C \approx 0.0013$).

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 is a longitudinal sectional view of an embodiment of the low-pressure mercury vapor discharge lamp in accordance with the invention;

Fig. 2A is a longitudinal view of an embodiment of the low-pressure mercury vapor discharge lamp with a striped conductive layer;

Fig. 2B is a longitudinal view of an embodiment of the low-pressure mercury vapor discharge lamp with a spiral conductive layer, and

Fig. 3 is a cross-sectional view of an embodiment of a compact fluorescent lamp comprising a low-pressure mercury vapor discharge lamp according to the invention;

The Figures are purely diagrammatic and not drawn to scale. Notably, some dimensions are shown in a strongly exaggerated form for the sake of clarity. Similar components in the Figures are denoted as much as possible by the same reference numerals.

Fig. 1 shows a low-pressure mercury vapor discharge lamp comprising a glass discharge vessel having a tubular portion 11 about a longitudinal axis 2, which discharge vessel transmits radiation generated in the discharge vessel 10 and is provided with a first and a second end portion 12a; 12b, respectively. In this example, the tubular portion 11 has a length L_{dv} of 120 cm and an inside diameter D_{in} of 24 mm. The discharge vessel 10 encloses, in a gastight manner, a discharge space 13 containing a filling of mercury and an inert gas mixture comprising, for example, argon. The side of the tubular portion 11 facing the discharge space 13 is provided with a luminescent layer 17 which comprises a luminescent material (for example a fluorescent powder) which converts the ultraviolet (UV) light generated by fallback of the excited mercury into (generally) visible light. In the example of Fig. 1, means for maintaining a discharge in the discharge space 13 are electrodes 20a; 20b arranged in the discharge space 13, said electrodes 20a; 20b being supported by the end portions 12a; 12b. Each electrode 20a; 20b is a winding of tungsten covered with an electron-emitting substance, in this case a mixture of barium oxide, calcium oxide, and strontium oxide. Current-supply conductors 30a, 30a'; 30b, 30b' of the electrodes 20a; 20b, respectively, pass through the end portions 12a; 12b and issue from the discharge vessel 10 to the exterior. The current-supply conductors 30a, 30a'; 30b, 30b' are connected to contact pins 31a, 31a'; 31b, 31b' which are secured to a lamp cap 32a, 32b. In general, an electrode ring (not shown in Fig. 1) is arranged around each electrode 20a; 20b, on which ring a glass capsule for dispensing mercury is clamped.

In the example of Fig. 1, a conductive layer 16 is disposed on an outer surface of the discharge vessel (10). The conductive layer 16 surrounds the discharge in the discharge space 13. In addition, the conductive layer 16 is provided with potential means (not shown in Fig. 1) for applying a potential to the conductive layer 16 during operation of the discharge lamp. According to a preferred embodiment of the invention, the conductive layer is made of tin oxide (SnO_2).

In the example shown in Fig. 1, the electrode 20a; 20b is surrounded by an electrode shield 22a; 22b which is, preferably, made from a ceramic material. Preferably, the electrode shield is made from a ceramic material comprising aluminum oxide. Particularly suitable electrode shields are manufactured from so-called densely sintered Al_2O_3, also referred to as PCA.

Preferably, a potential difference of 100 V is kept between the conductive coating and the discharge in the discharge space.

Fig. 2A schematically shows a longitudinal view of an embodiment of the low-pressure mercury vapor discharge lamp with a striped conductive layer 26.

Fig. 2B schematically shows a longitudinal view of an embodiment of the low-pressure mercury vapor discharge lamp with a spiral conductive layer 36.

Fig. 3 shows a compact fluorescent lamp comprising a low-pressure mercury vapor discharge lamp. Similar components in Fig. 3 are denoted as much as possible by the same reference numerals as in Fig. 1. The low-pressure mercury vapor discharge lamp is in this case provided with a radiation-transmitting discharge vessel 10 having a tubular portion 11 enclosing, in a gastight manner, a discharge space 13 having a volume of approximately 25 cm^3. The discharge vessel 10 is a glass tube which is at least substantially circular in cross-section and the (effective) internal diameter D_{in} of which is approximately 10 mm. In this example, the tubular portion 11 has a total length L_{dv} (not shown in Fig. 3) of 40 cm. The tube is bent in the form of a so-called hook and, in this embodiment, it has a number of straight parts, two of which, referenced 31, 33, are shown in Fig. 2. The discharge vessel further comprises a number of arc-shaped parts, two of which, referenced 32, 34, are shown in Fig. 3. The discharge vessel 10 can, in a preferable embodiment, be closed in a gastight manner by a disc stem. Disc stem technology is quite common for conventional TV manufacturing. By using this technology in compact fluorescent lamps, frit sealing can be applied to close the burners. A melting glass then makes the vacuum-tight connection between burner tube and disc stem. This process occurs typically below 600°C. Because of this lower temperature, the internal ambient can be kept much cleaner than with conventional processing. The side of the tubular portion 11 facing the discharge space 13 is provided with a luminescent layer 17. In an alternative embodiment, the luminescent layer has been omitted. The discharge vessel 10 is supported by a housing 70 which also supports a lamp cap 71 provided with electrical and mechanical contacts 73a, 73b, which are known per se. In addition, the discharge vessel 10 is surrounded by a light-transmitting envelope 60 which is attached to the lamp housing 70. The light-transmitting envelope 60 generally has a matt appearance.

In the example of Fig. 3, a conductive layer 16 is disposed on an outer surface of the discharge vessel 10. The conductive layer 16 surrounds the discharge in the discharge space 13. In addition, the conductive layer 16 is provided with potential means (not shown in Fig. 3) for applying a potential to the conductive layer 16 during operation of the discharge lamp.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. A low-pressure mercury vapor discharge lamp comprising:

- a discharge vessel (10) with a length L_{dv} and with an internal diameter D_{in},
- the discharge vessel (10) enclosing, in a gastight manner, a discharge space (13) provided with a inert gas mixture and with mercury,
- the discharge vessel (10) comprising discharge means for maintaining a discharge in the discharge space (13),
- a conductive layer (16) being disposed, the conductive layer (16) at least partially surrounding the discharge in the discharge space (13) and being provided with potential means for applying a potential to the conductive layer (16),
- the ratio of the weight of mercury m_{Hg} in the discharge vessel (10) and the product of the internal diameter D_{in} and the length of the discharge vessel L_{dv} being given by the relation:

$$\frac{m_{Hg}}{D_{in} \times L_{dv}} = C,$$

wherein $C \leq 0.01\ \mu g/mm^2$.

2. A low-pressure mercury vapor discharge lamp as claimed in claim 1, characterized in that the conductive layer (16) is translucent.

3. A low-pressure mercury vapor discharge lamp as claimed in claim 1 or 2, characterized in that the conductive layer (16) comprises tin oxide.

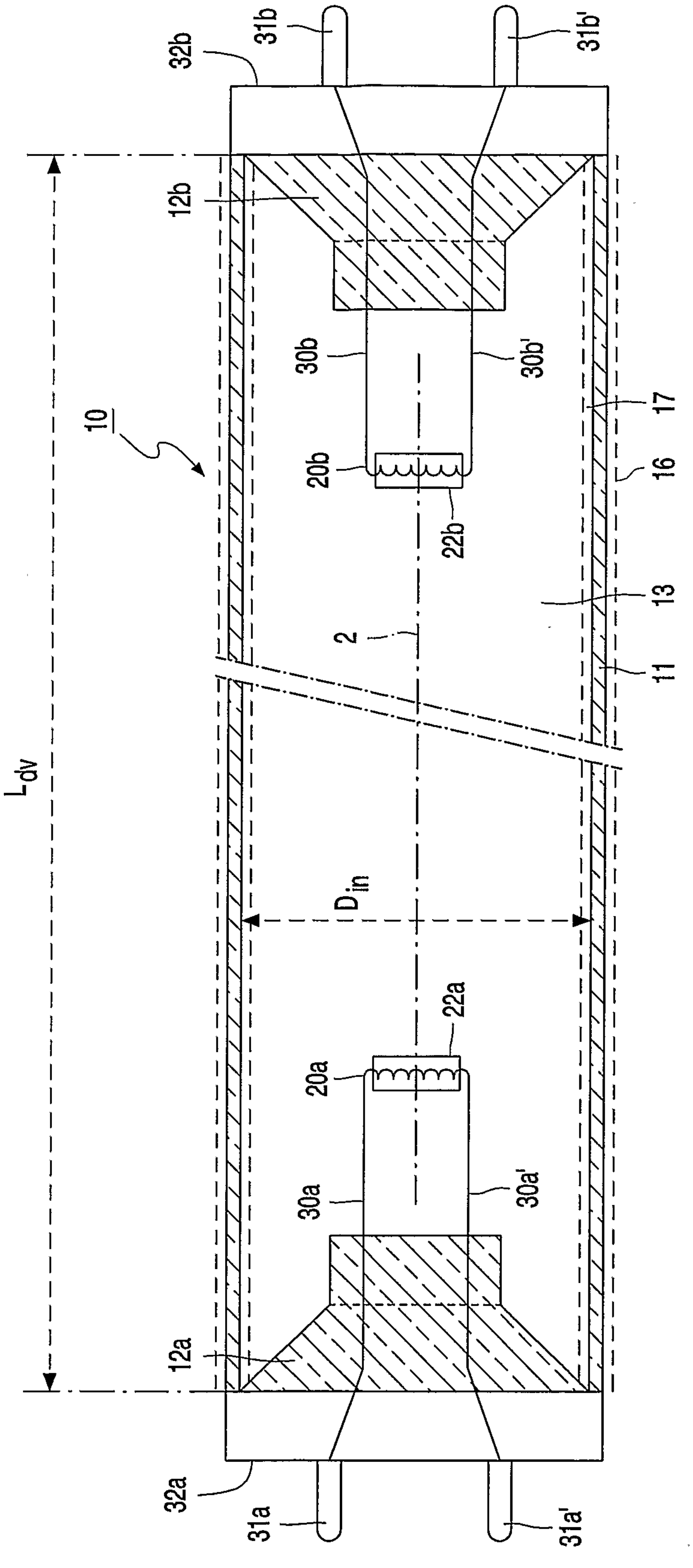
4. A low-pressure mercury vapor discharge lamp as claimed in claim 1 or 2, characterized in that the conductive layer (16) is provided on an outer surface of the discharge vessel (10).

5. A low-pressure mercury vapor discharge lamp as claimed in claim 1 or 2, characterized in that the conductive layer is striped (26) or forms a spiral (36).

6. A low-pressure mercury vapor discharge lamp as claimed in claim 1 or 2, characterized in that $0.0005 \leq C \leq 0.005$ μg/mm^2.

7. A low-pressure mercury vapor discharge lamp as claimed in claim 1 or 2, characterized in that the discharge vessel (10) contains less than 0.1 mg mercury.

8. A compact fluorescent lamp comprising a low-pressure mercury-vapor discharge lamp as claimed in claim 1 or 2, characterized in that a lamp housing (70) is attached to the discharge vessel (10) of the low-pressure mercury-vapor discharge lamp, which lamp housing is provided with a lamp cap (71).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20b
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12a
32a
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31a'

FIG. 1

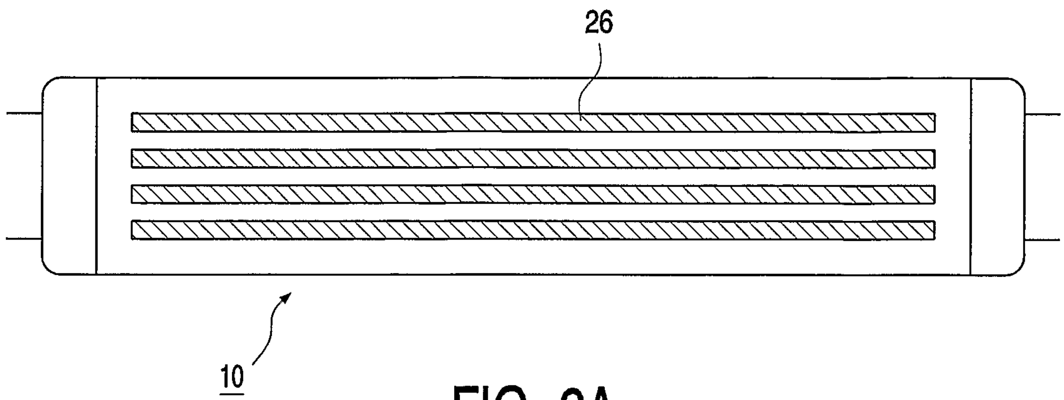

FIG. 2A

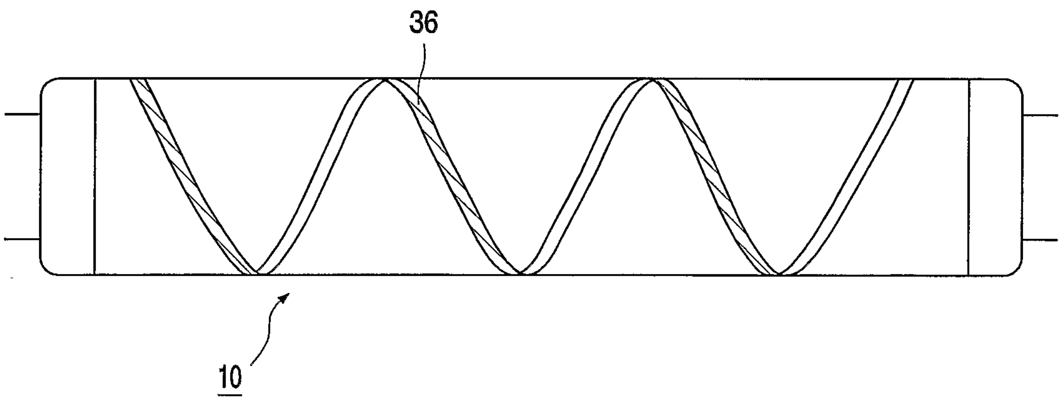

FIG. 2B

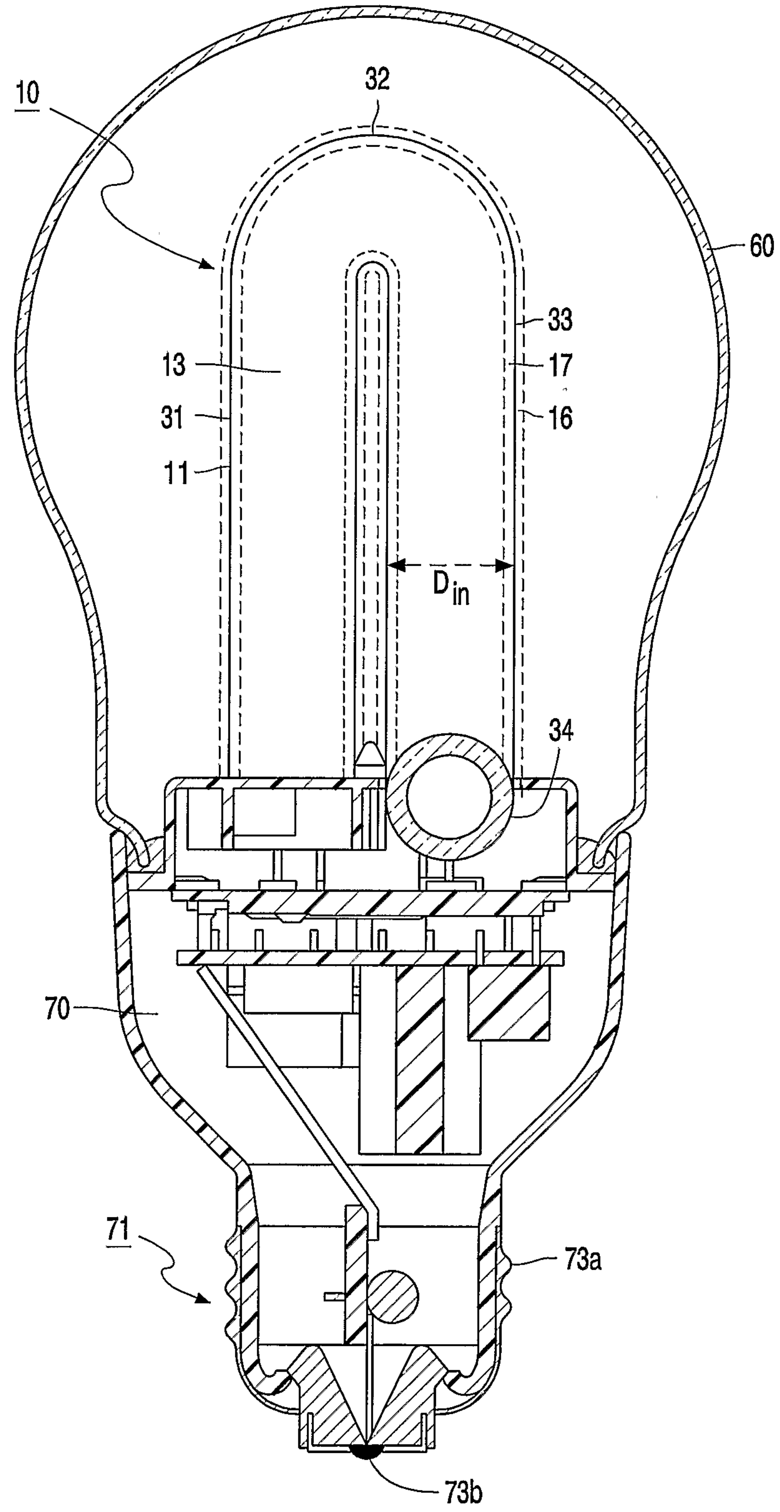

FIG. 3