(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 059 659 A1

(12) EUROPEAN PATENT APPLICATION

published in accordance with Art. 158(3) EPC

(43) Date of publication:
13.12.2000 Bulletin 2000/50

(21) Application number: **99961407.6**

(22) Date of filing: **27.12.1999**

(51) Int. Cl.[7]: **H01J 65/00**

(86) International application number:
PCT/JP99/07323

(87) International publication number:
WO 00/41215 (13.07.2000 Gazette 2000/28)

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **28.12.1998 JP 37247198**

(71) Applicant:
Japan Storage Battery Co., Ltd.
Kyoto-shi, Kyoto 601-8520 (JP)

(72) Inventors:
- **YOSHIKAWA, Tomoya**
  Japan Storage Battery Co., Ltd.
  Kyoto-shi Kyoto-fu 601-8520 (JP)
- **EZAKI, Shingo**
  Japan Storage Battery Co., Ltd.
  Kyoto-shi Kyoto-fu 601-8520 (JP)
- **SAKAMOTO, Hiromi**
  Japan Storage Battery Co., Ltd.
  Kyoto-shi Kyoto-fu 601-8520 (JP)
- **YOSHIDA, Masahiro**
  Japan Storage Battery Co., Ltd.
  Kyoto-shi Kyoto-fu 601-8520 (JP)

(74) Representative:
Herrmann-Trentepohl, Werner, Dipl.-Ing. et al
Patentanwälte
Herrmann-Trentepohl
Grosse - Bockhorni & Partner
Forstenrieder Allee 59
81476 München (DE)

(54) SILENT DISCHARGE TUBE AND ITS USE METHOD

(57) The power consumption of a silent discharge lamp having a structure in which an inner tube is disposed in the interior of an outer tube is reduced. In addition, the lifetime is extended.

For this purpose, in a silent discharge lamp including: a discharge vessel which has an outer tube and an inner tube, the inner tube being disposed in an interior of the outer tube, and in which a space that is formed by being surrounded by an inner face of the outer tube and an outer face of the inner tube is filled with a discharge gas; an outside electrode provided on an outer face of the outer tube; and an inside electrode provided on an inner face of the inner tube, one of the outside electrode and the inside electrode is provided over all circumference of a tube, and the other one is provided in a part of a tube circumference, thereby allowing discharge to be performed in the part of the tube circumference. The electrode is moved at the end of the lifetime, so that a face in which discharge is not caused is newly used.

Fig.1(A)

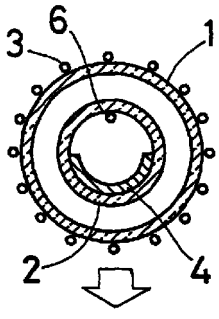
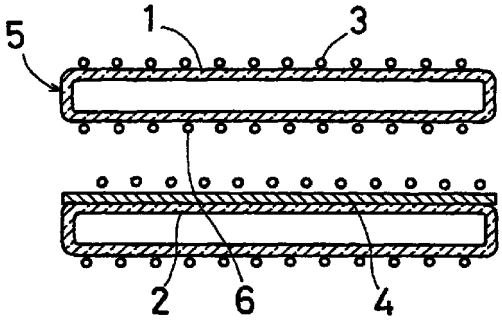


Fig.1(B)



EP 1 059 659 A1

Description

Technical Field

[0001] The invention relates to a silent discharge lamp which is to be used as, for example, an ultraviolet light source for dry cleaning or modification using ultraviolet rays.

Background Art

[0002] A silent discharge lamp has a structure in which electrodes are provided on an outer face of a discharge vessel that is made of a dielectric material such as quartz and that is filled with a discharge gas such as argon or xenon. The silent discharge lamp is an excellent light source which emits ultraviolet rays having a specific wavelength with superior monochromaticity when a voltage is applied across the electrodes. Especially, a silent discharge lamp having a structure in which a discharge vessel wherein an inner tube is disposed in the interior of an outer tube and a space to be filled with a discharge gas is formed by an inner face of the outer tube and an outer face of the inner tube is used, and in which an outside electrode is disposed on an outer face of the outer tube and an inside electrode is disposed on an inner face of the inner tube involves advantages that the structure is simple, and that the production is easily performed. Among such lamps, a lamp using a cylindrical tube can be produced at a low cost by using a quartz tube or the like which is a general product, and thus such a lamp is superior in this point.

[0003] Figs. 4 and 5 are diagrams showing general structures of silent discharge lamps using cylindrical tubes. Both of the silent discharge lamps shown in Figs. 4 and 5 have a structure in which a cylindrical inner tube 2 is coaxially disposed in the interior of a cylindrical outer tube 1, and a space to be filled with a discharge gas is formed by closing both ends thereof with covers 5, and have a structure in which an outside electrode 3 is provided on an outer face of the outer tube 1 over all circumference thereof, and an inside electrode 4 is provided on an inner face of the inner tube 2 over all circumference thereof. In the silent discharge lamp shown in Fig. 4, the outside electrode 3 is a metal net, and the inside electrode 4 is a cylindrical metal tube. The electrodes are provided so as to be closely in contact with the outer face of the outer tube 1 and the inner face of the inner tube 2, respectively. In the silent discharge lamp shown in Fig. 5, the outside electrode 3 is a metal net, and the inside electrode 4 is a coil-like metal wire. The electrodes are provided so as to be closely in contact with the outer face of the outer tube 1 and the inner face of the inner tube 2, respectively.

[0004] As described above, in a silent discharge lamp having a structure in which a discharge vessel wherein an inner tube is disposed in the interior of an outer tube and a space to be filled with a discharge gas is formed by an inner face of the outer tube and an outer face of the inner tube is used, an outside electrode is provided on an outer face of the outer tube, and an inside electrode is provided on an inner face of the inner tube, both of the outer electrode and the inside electrode are provided over all circumferences of the tubes.

[0005] In the case where a silent discharge lamp is used, also in the case where any other light source is used, it is preferred that the power consumption is as small as possible.

[0006] The first object of the invention is the same as described above, and it is an object of the invention to decrease a power consumption of a silent discharge lamp having the above-described structure in which an inner tube is disposed in the interior of an outer tube.

[0007] As in the case of any other light sources, the intensity of irradiated light lowers as the use of a silent discharge lamp is continued. At a stage where the intensity lowers to be equal to or lower than a certain value, the silent discharge lamp is replaced with a new one. However, a silent discharge lamp is very expensive as compared with other light sources, so that it is very important, for example, in a sense of lowering the running cost of an apparatus in which the discharge lamp is used, that the lifetime is extended as long as possible. Thus, it is a second object of the invention to extend the lifetime of a silent discharge lamp.

Disclosure of Invention

[0008] The invention has been conducted by paying attention to a manner of using a silent discharge lamp, and is characterized in that a discharge region is limited to a side of a part of a tube side face (a part of a tube circumference). Specifically, in a conventional silent discharge lamp, the discharge region exists over all circumference of the tube side face, and uniform discharge is required over all circumference. The inventors of the invention have become aware of the fact that it is not necessary to perform uniform discharge over all circumference, but it is sufficient that the uniform discharge is performed only on a specific side. This is because, in many using conditions, the illumination face is positioned in a direction of a side of a part of the tube side face. In such using conditions, conventionally, light emission exists in an ineffective portion with respect to the illumination face, so that an electric power is waste from the above-mentioned viewpoint, the invention is a silent discharge lamp in which discharge is performed on a specific side of a tube side face (a part of a tube circumference), which comprises: a discharge vessel which has an outer tube and an inner tube disposed in an interior of the outer tube, and which is configured by filling a space formed by being surrounded by an inner face of the outer tube and an outer face of the inner tube, with a discharge gas; an outside electrode provided on an outer face of the outer tube; and an inside electrode provided on an inner face of the inner tube,

characterized in that at least one of the outside electrode and the inside electrode is provided in a part of a tube circumference, and discharge is performed in the part of the tube circumference, the invention is a silent discharge lamp comprising: a discharge vessel which has an outer tube and an inner tube, the inner tube being disposed in an interior of the outer tube, and in which a space formed by being surrounded by an inner face of the outer tube and an outer face of the inner tube is filled with a discharge gas; an outside electrode provided on an outer face of the outer tube; and an inside electrode provided on an inner face of the inner tube, characterized in that one of the outside electrode and the inside electrode is disposed over all circumference of the tube, and the other one is disposed in a part of the tube circumference, thereby allowing discharge to be performed in a part of the tube circumference. When one of the electrodes is provided over all circumference of the tube as described above, there arises an advantage that stable discharge can be easily maintained.

[0009] The inventors of the invention have found that, even if, instead of the prior-art configuration in which both of the electrodes are provided over all circumferences of the tubes, an electrode is disposed in a part of the tube circumference as described above, light irradiation having sufficient intensity and uniform intensity distribution can be obtained. Based on this finding, the irradiation direction of light is limited to a part of the tube circumference, so that the substantial power consumption can be reduced.

[0010] In addition, one of causes of the reduction of the light intensity with the use is the reduction of light transmittance of the outer tube or the inner tube due to the irradiated light from the discharge lamp itself. If discharge is performed in a part of the tube circumference, also the irradiated light is irradiated from the part of the tube circumference, so that the reduction of light transmittance can be prevented from occurring in a tube circumference portion from which irradiated light is not emitted. When the intensity of irradiated light from the discharge lamp is lowered, therefore, a portion in which the light transmittance is not reduced can be used by displacing the position of the electrode, or by other means. Thus, it is possible to substantially extend the lifetime of the silent discharge lamp.

[0011] The method of using a silent discharge lamp of the invention is a using method by which the lifetime can be substantially extended as described above, characterized in that, in the case where the light transmittance of the outer tube becomes lower than a predetermined value, the discharge region is changed, and discharge is performed in a tube circumference portion in which discharge is has not yet performed.

Brief Description of Drawings

[0012]

Fig. 1 is a schematic sectional structural diagram showing the structure of a silent discharge lamp of a first embodiment of the invention.

Fig. 2 is a schematic sectional structural diagram showing the structure of a silent discharge lamp of a second embodiment of the invention.

Fig. 3 is a section view showing a specific example of the silent discharge lamp of the invention.

Fig. 4 is a schematic diagram showing a general structure of a silent discharge lamp using cylindrical tubes.

Fig. 5 is a schematic diagram showing a general structure of a silent discharge lamp using cylindrical tubes.

Fig. 6 is a section view showing another specific example of the silent discharge lamp of the invention.

Fig. 7 is a diagram showing an example of a silent discharge lamp having a regular triangular section shape.

Fig. 8 is a diagram showing a condition in which five silent discharge lamps shown in Fig. 7 are disposed.

Fig. 9 is a diagram showing a specific example in which a section shape perpendicular to the axis is square.

Fig. 10 is a structural diagram showing the structure of a silent discharge lamp of a third embodiment of the silent discharge lamp of the invention.

Best Mode for Carrying Out the Invention

[0013] When the silent discharge lamp of the invention is to be produced, a dielectric material such as glass is used as a material for an outer tube and an inner tube. In the case where discharge is performed in a part of a tube circumference as in the invention, it is preferred that irradiated light due to dielectric barrier discharge is taken out from an outer face of the outer tube to the outside of a discharge vessel (in order to prevent a portion of the discharge vessel from which light is not irradiated, from deteriorating). For this reason, the outer tube is preferably made of a material for sufficiently transmitting the irradiated light. In the case where a xenon gas is used as a discharge gas and ultraviolet rays of 172 nm is irradiated, for example, synthetic quartz is preferred, and synthetic quartz containing OH groups of 100 ppm or more, and more preferably 200 ppm or more is more preferred.

[0014] As a shape for the outer tube and the inner tube, it is possible to adopt various shapes in which a section perpendicular to the tube axial direction is a circle, a polygon, or the like. In order to uniformalize the distance between the inside and outside electrodes in a

discharge space and to obtain irradiated light with uniform intensity distribution, it is preferred that the section shapes of the outer tube and the inner tube which are perpendicular to the axial direction thereof are similar. It is preferred that they are disposed coaxially. In view of the case where the lamp is used while changing the discharge region, it is preferred that the section shape is a shape having symmetry such as a regular polygon, a circle, or an ellipse.

[0015] The shape of the outside electrode and the inside electrode is preferably a shape which is closely in contact with a tube surface in agreement with the shape of the discharge vessel. As for the electrode on the side for taking out the irradiated light, a material and a shape which allow light to transmit are required. For example, the electrode is configured by a conductive net made of an etching metal, a metal net, or the like. In the case of the invention, especially, it is preferred that the outside electrode has an optically transparent characteristic (light emitted by discharge can be easily transmitted therethrough), and the inside electrode has an optically opaque characteristic (in order to prevent light irradiated from an inner face of the inner tube from entering a portion of the discharge vessel which does not emit light). In this case, for example, it is possible that a conductive netlike electrode is formed so as to be closely in contact with an outer face of the outer tube. The inside electrode can be formed by a method in which the inside electrode is directly formed on an inner face of the inner tube by vapor deposition, a method in which a metal plate having a shape in agreement with the shape of the inner face of the inner tube is inserted, or other methods.

[0016] In addition, as for the outside electrode and the inside electrode, both of them may be provided in a part of the tube circumference, or one of them may be provided in a part of the tube circumference. If the electrode occupies a larger proportion with respect to the tube circumference, the whole of the tube circumference eventually performs discharge. In view of the case where the lamp is used while changing the discharge region, it is preferred that the electrode occupies about a half proportion or less of the tube circumference. Especially, in view of the case where the lamp is used while changing the discharge region, at least one of the electrodes provided in a part of the tube circumference is preferably provided so that the length on the tube circumference is approximately a fraction of a positive number of the length of the tube circumference. This is because the tube circumference can be used evenly by changing the region at times equal to the positive number.

[0017] On the contrary, if the proportion is too small, the discharge region is also too small with respect to the size of the discharge lamp, so that the efficiency is deteriorated. Also, it is difficult to obtain the uniformity of the intensity of irradiated light. Therefore, it is preferred that the proportion is set to be about one-fourth or more of the tube circumference.

[0018] The electrode provided in a part of the tube circumference is preferably disposed so as to be replaceable. This is because, in the case where the lamp is used while changing the discharge region, the position of the electrode is required to be changed in agreement with the region. The electrode provided in a part of the tube circumference may be configured by, for example, two electrodes which are separated along the tube circumference to be disposed with forming a gap so as not to be in contact with each other, and only one of them may be electrically connected to a power source or the ground. In this case, the other electrode does not function as an electrode, so that it is substantially regarded as not being provided. Thus, it is possible to eliminate a labor of removing and changing the electrode when the discharge region is to be changed.

[0019] As the discharge gas with which a space formed by being surrounded by an inner face of the outer tube and an outer face of the inner tube is to be filled, for example, a rare gas such as xenon, argon, or neon, a halogen gas such as fluorine, or chlorine can be used singly or in combination.

[0020] The space in the discharge vessel which is to be filled with such a discharge gas is not necessarily divided in the tube circumference direction, but it is effective that a partition wall is provided in the discharge vessel for dividing the space in the discharge vessel in the tube circumference direction. For example, by separating gases in the discharge region and outside the discharge region from each other, it is possible to prevent the luminous efficiency from lowering due to the mixing of a gas in an excited state with a gas not in an excited state.

[0021] In addition to the above-described function of the partition wall, or aside from the above-described function, it is effective that the partition wall is formed as a light blocking wall having a light blocking function. This prevents the irradiated light from traveling in the space in the discharge vessel to enter a tube circumference face in which discharge is not performed. According to this configuration, it is possible to prevent the light transmittance from lowering in the tube circumference face in which discharge is not performed, and it is possible to effectively extend the lifetime in the case where the lamp is used while changing the discharge region.

[0022] In the case where a partition wall is provided, the material preferably has a coefficient of thermal expansion which is close to a coefficient of thermal expansion of the outer tube and the inner tube. For example, the outer tube, the inner tube, and the partition wall may be configured by quartz of a material through which light having a wavelength emitted from the discharge lamp is not transmitted. In the case where the silent discharge lamp irradiates ultraviolet rays of 172 nm, a tube material on the side from which the ultraviolet rays are taken out may be a synthetic quartz, and may contain OH groups of 100 ppm or more, and more

preferably 200 ppm or more. In the case where the partition wall is a light blocking wall, quartz or the like which is opaque to the irradiated ultraviolet rays may be used. Especially, in the case where the silent discharge lamp irradiates ultraviolet rays of 172 nm, it may be made of quartz such as fused quartz, and especially of a quartz plate containing 100 ppm or smaller of OH groups. Fig. 3 is a section view of a section perpendicular to the axial direction of the tube and showing specific examples in the case where one of the outside electrode and the inside electrode is provided over all circumference of the tube, and the other one is provided in a part of the tube circumference. In the figure, (A) is a view in the case where the inside electrode is provided over all circumference of the tube, and the outside electrode is provided in a part of the tube circumference, and (B) is a view in the case where the outside electrode is provided over all circumference of the tube, and the inside electrode is provided in a part of the tube circumference.

[0023] A silent discharge lamp shown in Fig. 3(A) has a structure in which a cylindrical inner tube 2 is coaxially disposed in the interior of a cylindrical outer tube 1, an outside electrode 3 of a metal net is provided on an outer face of the outer tube 1 over a half of the circumference, and an inside electrode 4 of a deposited metal film is provided on an inner face of the inner tube 2 over all circumference. An illumination face is positioned in a direction indicated by the arrow in the figure. A silent discharge lamp shown in Fig. 3(B) has a structure in which a cylindrical inner tube 2 is coaxially disposed in the interior of a cylindrical outer tube 1, an outside electrode 3 of a metal net is provided on an outer face of the outer tube 1 over all circumference, and an inside electrode 4 of a semi-cylindrical metal plate is closely secured by a coil-like reinforcing member inserted into the inner tube 2, so that the inside electrode is provided over a half of the circumference. An illumination face is positioned in a direction indicated by the arrow in the figure.

[0024] The electrode provided over all circumference of the tube as described above may be one of the outside electrode and the inside electrode. The electrode provided in a part of the tube circumference may be closely secured to the tube face in a rotatable manner, and, in the case of a cylindrical tube, preferably provided over a half of the circumference. This is because the other portion of the tube face can be used by moving the electrode provided in a part. Especially, by rotating by 180°, the opposite side can be easily used for discharge. Thus, the lifetime can be substantially extended.

[0025] Preferably, the outside electrode may be provided over all circumference of the tube, and the inside electrode may be provided in a part of the tube circumference. In this case, it is preferable that the shape of the inside electrode is a shape which substantially agrees with the shape of the inner face of the inner tube formed by cutting the inner tube along the axis thereof, and the inside electrode is closely secured to the inner tube by a spring-like conductive reinforcing member. In addition, as shown in Fig. 3(B), it is more preferable that a cylindrical outer tube and a cylindrical inner tube are coaxially disposed, and a semi-cylindrical inside electrode is closely secured by a coil-like electrode inserted into the inner tube. In this case, the inside electrode may be closely secured to the inner face of the inner tube in a rotatable manner. According to this configuration, in the case where the lifetime of the discharge lamp expires by the deterioration of the tube, the opposite side can be used for discharge by rotating the inside electrode by 180°. Thus, it is possible to substantially extend the lifetime.

[0026] As described also in the above, in the silent discharge lamp of the invention, the shapes of the outer tube and the inner tube are not particularly limited. For example, it is preferred that a cylindrical tube of quartz glass or the like is used because it is easily produced at a low cost. In this case, for example, the outer tube and the inner tube are coaxially disposed.

[0027] Fig. 6 is a view showing a specific example in the case where both of the outside electrode and the inside electrode are provided in a part of the tube circumference, and a light blocking wall is provided, (A) is a section view of a section perpendicular to the axial direction of the tube, and (B) is a section view of a section in parallel to the axial direction and in the A-A direction.

[0028] The silent discharge lamp shown in Fig. 6 has the following structure. A cylindrical inner tube 2 is coaxially disposed in the interior of a cylindrical outer tube 1. An outside electrode 3 of a metal net is provided on an outer face of the outer tube 1 over a half of the circumference. An inside electrode 4 of a semi-cylindrical metal plate is closely secured to an inner face of the inner tube 2 by a coil-like reinforcing member (not shown in the figure) inserted into the inner tube 2. The inside electrode is provided over a half of the circumference. Light blocking wall stoppers 7 are provided. Two light blocking walls 8 configured by a fused quartz plate are inserted into a discharge vessel so as to be supported by the stoppers. In addition, in order to prevent the inside electrode 4 from rotating to be displaced, a rotation stopper 9 is provided. The light blocking wall stoppers 7 and the rotation stopper 9 are attached by melting and bonding quartz beads to the tube wall.

[0029] In the silent discharge lamp of the embodiment, since the light blocking wall 7 is provided, the irradiated light can not enter the side of the portion of the tube circumference in which the electrode is not provided, through the discharge space. Thus, the deterioration on the side of the tube is greatly suppressed. As in this example, by providing a rotation stopper for the electrode provided in a part of the tube circumference, accidental displacement of the electrode can be prevented from occurring, and it is possible to ensure the

setting accuracy of the illumination intensity on the illumination face because the light is emitted only from a specific face of the silent discharge lamp. In addition, the rotation stopper exerts also a function of positioning the electrode, so that, in the case where the emission region is changed, a new irradiation face can be easily and surely set.

[0030] Fig. 7 is a diagram showing an example of a silent discharge lamp in which a section shape perpendicular to the axis is a regular triangle. The silent discharge lamp shown in Fig. 7 has the following structure. An inner tube 2 of an angular cylindrical shape having a regular triangular section is coaxially disposed in the interior of an outer tube 1 of an angular cylindrical shape having a regular triangular section. An outside electrode 3 of a metal net is provided on a face corresponding to a side of an outer face of the outer tube 1. A plate-like inside electrode 4 is closely secured to a face corresponding to a side of an inner face of the inner tube 2 by a spring-like reinforcing member (not shown in the figure). In addition. three light blocking walls 8 configured by a quartz plate are inserted into the inside of a discharge vessel. Fig. 8 is a diagram showing a condition in which five silent discharge lamps shown in Fig. 7 are disposed. As seen from the figure, the section shape perpendicular to the axial direction is a triangle, so that an irradiation face on a plane can be configured by arranging them adjacently. Thus, it is possible to configure a flat light source having a large area without using a reflection plate or the like. In addition, the distance from the irradiation face to the sample face is constant, and hence it is possible to eliminate the variation in illumination intensity which, in the case of a silent discharge lamp having a circular section, may be caused by the light absorption on its way because the distance to the sample face is varied depending on the position of the irradiation face. Therefore, a light source apparatus can be produced in which provisions of an expensive irradiation window of synthetic quartz and a lamp house requiring a supply of inert gas such as N_2 are not required.

[0031] As described above, in the silent discharge lamp of the invention, when a discharge vessel in which angular-cylindrical outer and inner tubes having a triangular or quadrangular section shape perpendicular to the axis are coaxially disposed is used, it is possible to easily configure a flat light source having a large area. In addition, it is advantageously possible to eliminate an expensive irradiation window of synthetic quartz and a lamp house requiring a supply of an inert gas such as N_2.

[0032] As in this example, when the silent discharge lamp of the invention having the structure in which the discharge vessel is configured so that angular-cylindrical outer and inner tubes having an approximately regular triangular or square section shape perpendicular to the axis are coaxially disposed is used, a plurality of discharge faces having the same area can be ensured, and it is practical because the size of a placing region for the silent discharge lamp is not changed even when the discharge region is changed. The term "approximately" used in the approximately triangular or square section shape means that also a rounded corner is included because, for example, in the case of the silent discharge lamps shown in Fig. 7 and shown in Fig. 9 below, anything is not substantially changed even if the corner is rounded, and especially in the case where the discharge vessel is produced by working quartz glass or the like, the corner is usually rounded.

[0033] Fig. 9 is a diagram showing a specific example in the case where the section shape perpendicular to the axis is square, and both of the outside electrode and the inside electrode are provided in a part of the tube circumference.

[0034] A silent discharge lamp shown in Fig. 9 has the following structure. In the interior of an angular-cylindrical outer tube 1 having a rectangular section shape perpendicular to the axis, an angular-cylindrical inner tube 2 having a similar shape is coaxially disposed. An outside electrode 3 of a metal net is disposed on a face corresponding to a longer side of an outer face of the outer tube 1. An inside electrode 4 of a metal plate is closely secured to a face corresponding to a longer side of an inner face of the inner tube 2 by a spring-like reinforcing member (not shown in the figure) inserted into the inner tube 2.

[0035] In the silent discharge lamp of this example, the angular-cylindrical outer tube 1 and inner tube 2 are in contact with each other on faces corresponding to the shorter sides thereof, so that the portion functions as a partition wall and a light blocking wall. In the use, the connection between the electrode to be used and an external power source or the like is switched depending on the face to be used.

Embodiments

[0036] Fig. 1 is a schematic sectional structural diagram showing the structure of a silent discharge lamp of a first embodiment of the invention, (A) is a section view in a direction perpendicular to the axial direction of the tube, and (B) is a section view along the axis of the tube. The silent discharge lamp of the embodiment has the following structure. In the interior of a cylindrical outer tube 1 of synthetic quartz glass having a whole length of 300 mm and an inner diameter of 26 mm, a cylindrical inner tube 2 of synthetic quartz glass having a whole length of 300 mm and an outer diameter of 16 mm is coaxially disposed. Both ends are closed by a cover 5, and the interior is filled with a xenon gas. An outside electrode 3 configured by a stainless metal net is closely secured to an outer face of the outer tube 1 over all circumference. An inside electrode 4 configured by a semi-cylindrical aluminum plate having a whole length of about 300 mm is closely secured to an inner face of the inner tube 2 by a coil-like stainless steel electrode 6

inserted into the inner tube 2. The inside electrode is provided over a half of the circumference. A conductive wire for supplying an electric power to the inside electrode 4 is welded to an end portion of the coil-like stainless steel electrode, and an electric power is supplied to the inside electrode via the coil-like stainless steel electrode 6. The conductive wire is directly connected to the outside electrode 3 at an end portion thereof.

[0037] The lamp is used while an illumination face is positioned in a direction indicated by the arrow in the figure. In the case where the tube is clouded as a result of a use for a long time, the lamp is used while the inside electrode 4 is rotated by 180° and the opposite side is turned so as to face the illumination face. In the silent discharge lamp of the embodiment, ultraviolet rays of 172 nm are irradiated.

Fig. 2 is a schematic sectional structural diagram showing the structure of a silent discharge lamp of a second embodiment of the invention, (A) is a section view in a direction perpendicular to the axial direction of the tube, and (B) is a section view along the axis of the tube. The silent discharge lamp of this embodiment has the following structure. In the interior of a cylindrical outer tube 1 of synthetic quartz glass having a whole length of 1000 mm and an inner diameter of 26 mm, a cylindrical inner tube 2 of synthetic quartz glass having a whole length of 1000 mm and an outer diameter of 16 mm is coaxially disposed. An inside electrode 4 configured by three semi-cylindrical aluminum plates having a whole length of 330 mm is closely secured to an inner face of the inner tube 2 by a coil-like stainless steel electrode 6 inserted into the inner tube 2. The other portions are structured in the same manner as those in the first embodiment. The lamp is used while an illumination face is positioned in a direction indicated by the arrow in the figure.

[0038] As described above, the inner electrode has the structure in which a plurality of electrode plates are joined in the axial direction of the tube, so that a long silent discharge lamp can be easily produced. Thus, such a structure is preferred in this point.

[0039] Fig. 10 is a structural diagram showing the structure of a silent discharge lamp of a third embodiment of the invention, (A) is a front view, (B) is a top view, (C) is an A-A section view, and (D) is a partial section view. The silent discharge lamp of the embodiment has the following structure. In the interior of a cylindrical outer tube 1 of synthetic quartz glass having a whole length of 650 mm and an inner diameter of 26 mm, a cylindrical inner tube 2 of synthetic quartz glass having a whole length of 650 mm and an outer diameter of 16 mm is coaxially disposed. Both ends thereof are closed, and the interior is filled with a xenon gas. An outside electrode 3 configured by a stainless metal net is closely secured to an outer face of the outer tube 1 over all circumference by securing both end portions thereof to the outer face of the outer tube 1 by a clip 10. An inside electrode 4 configured by a semi-cylindrical aluminum plate having a whole length of 550 mm is closely secured to an inner face of the inner tube 2 by a coil-like stainless steel electrode 6 inserted into the inner tube 2. A conductive wire 11 for supplying an electric power to the inside electrode 4 is welded to an end portion of the coil-like stainless steel electrode 6, so that an electric power is supplied to the inside electrode 4 via the coil-like stainless steel electrode 6. The out-side electrode 3 is connected to the ground via the clip 10. Spot-like depressions are formed so as to protrude onto the inner face side by touching the inner tube 2 by an iron at a high temperature. The depressions function as a rotation stopper 9 for the inside electrode 4.

Industrial Applicability

[0040] According to the silent discharge lamp of the invention, on the illumination face in a predetermined direction, a higher illuminance can be obtained at an electric power which is equal to the prior art, and the same illuminance can be obtained at a lower electric power. Since a face on which discharge is not caused can be newly used, the lamp is economical. In addition, when the electrode provided in a part of the tube circumference is closely secured to the tube face in a rotatable manner, a face in which discharge is not caused can be newly used by moving the electrode at the end of the lifetime, or by changing the electrode to a new one. Thus, it is possible to substantially extend the lifetime.

Claims

1. A silent discharge lamp comprising: a discharge vessel which has an outer tube and an inner tube disposed in an interior of said outer tube, and which is configured by filling a space formed by being surrounded by an inner face of said outer tube and an outer face of said inner tube, with a discharge gas; an outside electrode provided on an outer face of said outer tube; and an inside electrode provided on an inner face of said inner tube, characterized in that at least one of said outside electrode and said inside electrode is provided in a part of a tube circumference, and discharge is performed in the part of said tube circumference.

2. A silent discharge lamp according to claim 1, wherein at least one of said electrodes provided in the part of said tube circumference has a length on said tube circumference which is about an integer fraction of a length of said tube circumference.

3. A silent discharge lamp according to claim 1 or 2, wherein said electrode provided in the part of said tube circumference is provided in a replaceable manner.

4. A silent discharge lamp according to claim 1, 2, or 3, wherein a partition wall for dividing said space in said discharge vessel in a tube circumference direction is provided in said discharge vessel.

5. A silent discharge lamp according to claim 4, wherein said partition wall is a light blocking wall.

6. A silent discharge lamp according to claim 4, wherein said partition wall is configured by a quartz plate of a material through which light having an irradiated wavelength is not transmitted.

7. A silent discharge lamp comprising: a discharge vessel which has an outer tube and an inner tube, said inner tube being disposed in an interior of said outer tube, and in which a space that is formed by being surrounded by an inner face of said outer tube and an outer face of said inner tube is filled with a discharge gas; an outside electrode provided on an outer face of said outer tube; and an inside electrode provided on an inner face of said inner tube, characterized in that one of said outside electrode and said inside electrode is provided over all circumference of said tube, and the other one is provided in a part of said tube circumference, thereby allowing discharge to be performed in the part of said tube circumference.

8. A silent discharge lamp according to claim 7, wherein said outside electrode is provided over all circumference of said tube, and said inside electrode is provided in a part of said tube circumference.

9. A silent discharge lamp according to claim 8, wherein said lamp comprises an inside electrode having a shape which substantially agrees with a shape of said inner face of said inner tube formed by cutting said inner tube along an axis, and said inside electrode is closely secured to said inner tube by a spring-like conductive reinforcing member.

10. A silent discharge lamp according to claim 9, wherein said outer tube having a cylindrical shape and said inner tube having a cylindrical shape are coaxially disposed, and said inside electrode having a semi-cylindrical shape is closely secured by a coil-like electrode inserted into said inner tube.

11. A silent discharge lamp according to claim 7, 8, 9, or 10, wherein said electrode disposed in the part of said tube circumference is closely secured to a tube face in a rotatable manner.

12. A silent discharge lamp according to claim 1, 2, 3, 4, 6, 7, 8, or 9, wherein said discharge vessel is configured by coaxially arranging angular-cylindrical outer and inner tubes having an approximately regular triangular or square section shape perpendicular to the axis.

13. A method of using said silent discharge lamp according to claim 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11, characterized in that, when light transmittance of said outer tube becomes lower than a predetermined value, a discharge region is changed, and discharge is performed in a tube circumference portion in which discharge has not yet performed.

Fig.1(A)

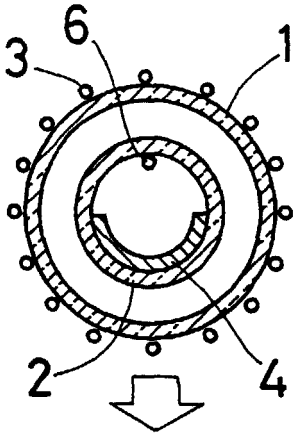


Fig.1(B)

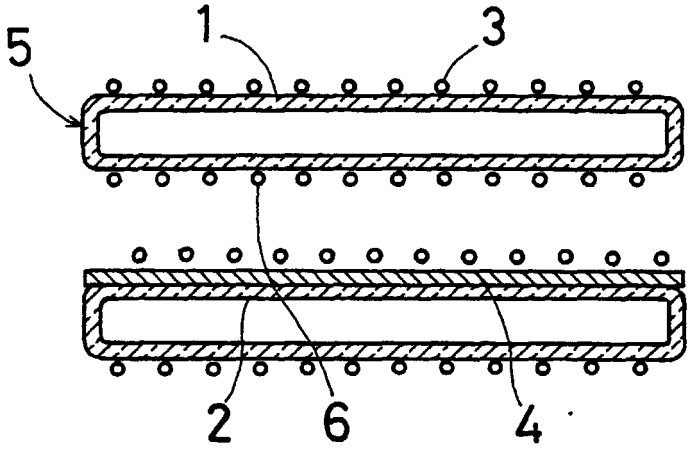


Fig.2(A)

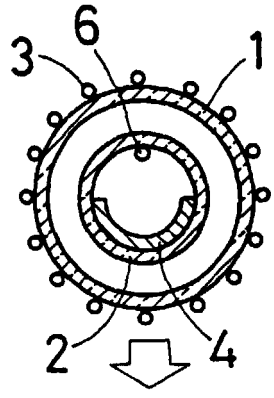


Fig.2(B)

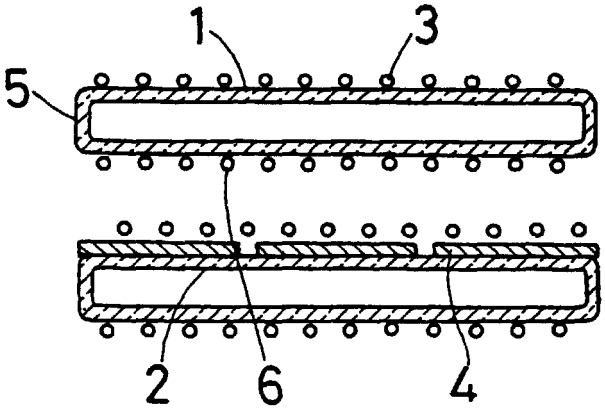


Fig.3(A)

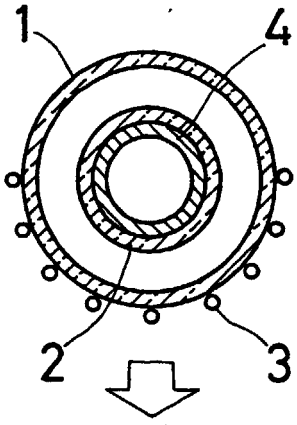


Fig.3(B)

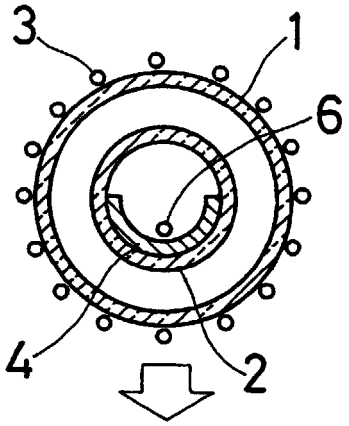


Fig.4(A)

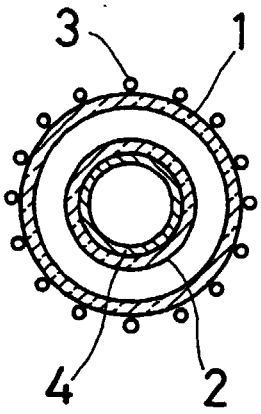


Fig.4(B)

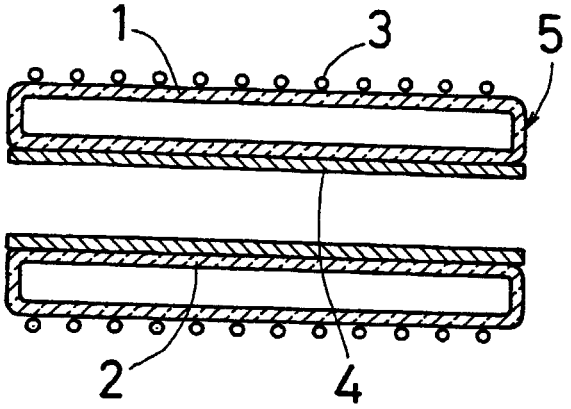


Fig.5(A)

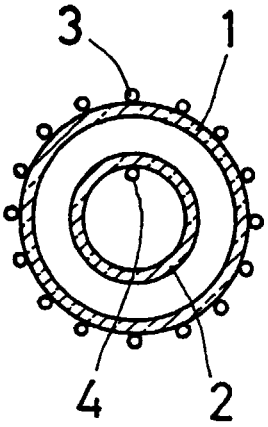


Fig.5(B)

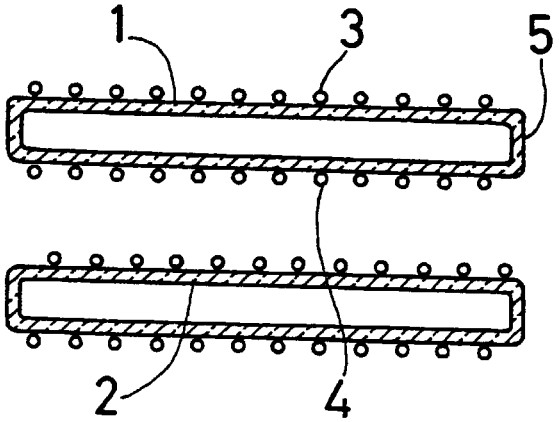


Fig:6(A)

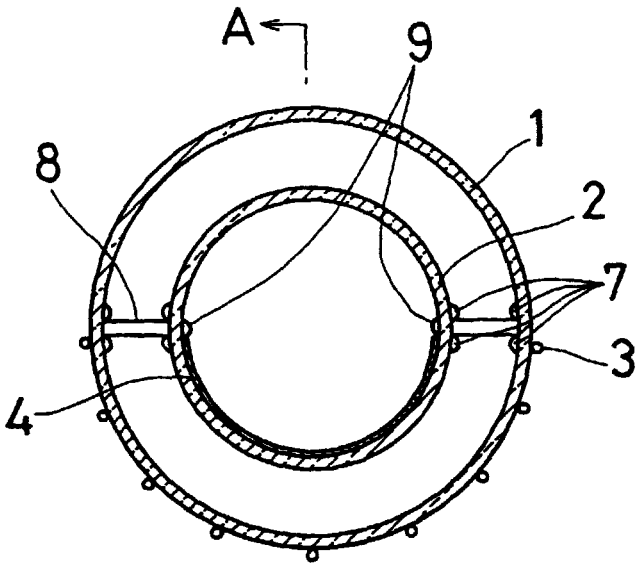


Fig.6(B)

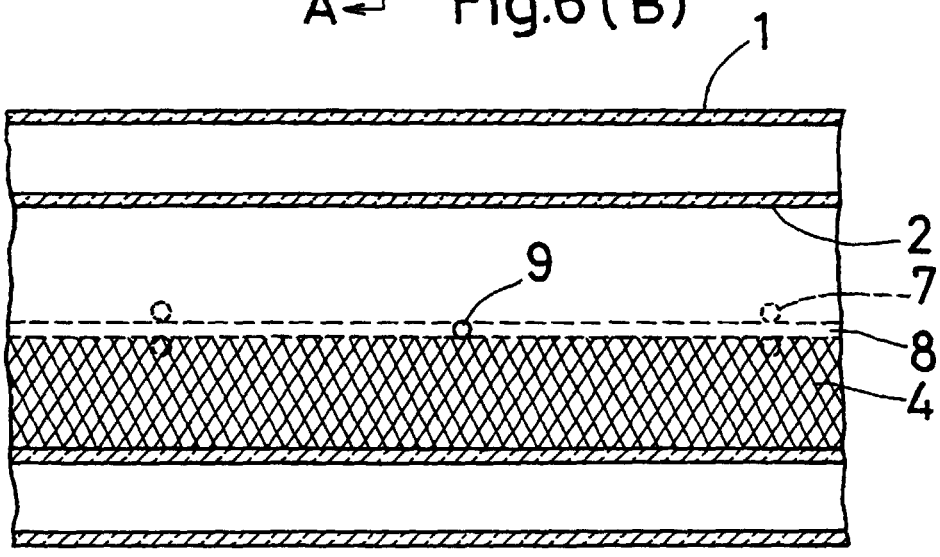


Fig.7

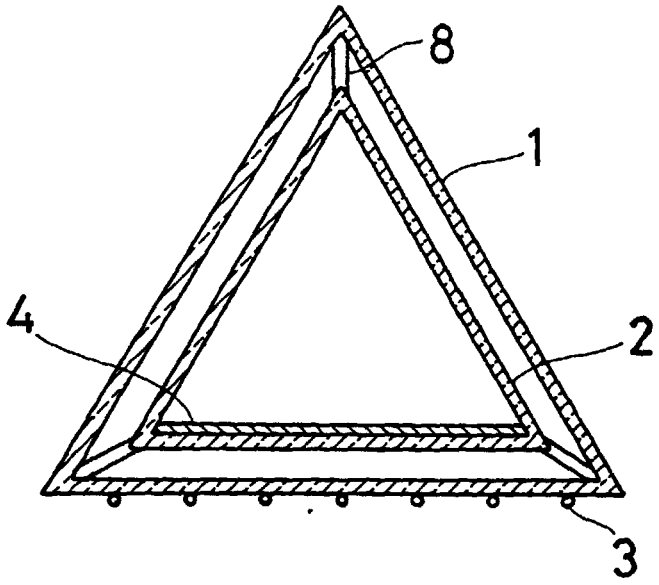


Fig.8

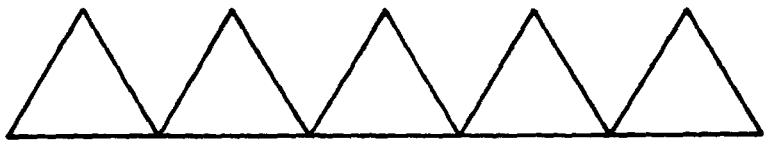


Fig.9

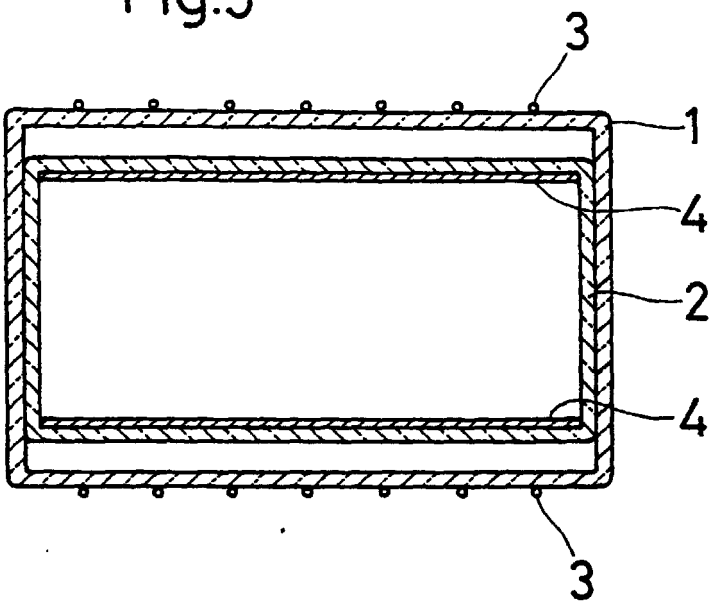


Fig.10(A)

Fig.10(B)

Fig.10(C)

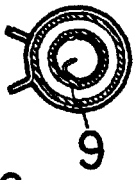
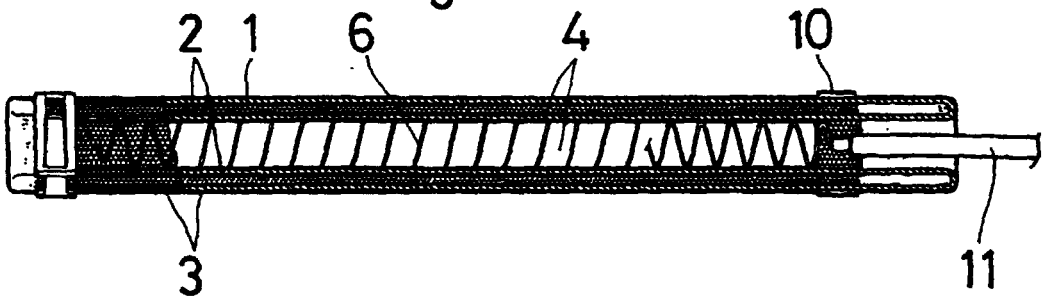


Fig.10(D)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/07323

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H01J65/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H01J65/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2000
Kokai Jitsuyo Shinan Koho 1971-2000 Jitsuyo Shinan Toroku Koho 1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US, 5214344, A (Asea Brown Boveri Ltd.), 25 May, 1993 (25.05.93), claim1; All Drawings claim1;1 All Drawings & EP, 458140, A & JP, 04-229671, A	1,7 8,9,10
X Y	JP, 5-174793, A (Asea Brown Boveri AG), 13 July, 1993 (13.07.93), Par. Nos. [0017]-[0029]; Figs. 1, 2 Par. Nos. [0017]-[0029]; Figs. 1, 2 & EP, 517929, A	1,7 8,9,10
Y	JP, 10-241633, A (USHIO INC.), 11 September, 1998 (11.09.98), Full text; all drawings (Family: none)	8,9,10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 March, 2000 (28.03.00)	11 April, 2000 (11.04.00)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)