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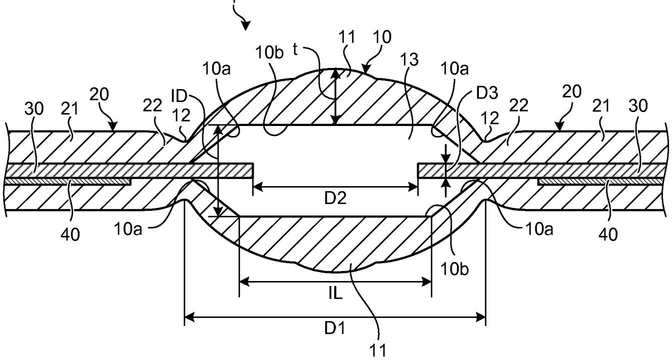
(54) **Discharge lamp**

(57) According to one embodiment, a discharge lamp (1) includes a light-emitting section (10), a pair of sealing sections (20, 20), and a pair of electrodes (30, 30). One ends of the pair of electrodes (30, 30) are disposed to be opposed to each other in a discharge space (13). An inner circumferential surface of the light-emitting section (10) includes a pair of taper surfaces (10a, 10a) expanding in an inner diameter from respective both end portions (12, 12) toward a center portion of the light-emitting section (10) in the direction in which the pair of electrodes extends and a cylindrical side circumferential surface (10b) contiguous to the pair of taper surfaces (10a, 10a) and extending along the direction in which the pair of electrodes (30, 30) extends. Length IL (mm) of the side circumferential surface (10b) in the direction in which the pair of electrodes (30, 30) extends, an inner diameter ID (mm) in the side circumferential surface (10b) of the light-emitting section (10), and maximum thickness t (mm) of the light-emitting section (10) satisfy the following Expression 1:

$$5.8 \leq (IL \times ID)/t \leq 9.8 \quad (1)$$

FIG.1



Description

FIELD

[0001] Embodiments described herein relate generally to a discharge lamp used in, for example, a headlight of an automobile.

BACKGROUND

[0002] A discharge lamp used as a headlight of an automobile has been requested to satisfy light-emitting efficiency necessary at steady time and satisfy a luminous flux maintenance factor necessary even after a long time elapses. In particular, if the discharge lamp is stably lit with electric power of 25 W at steady time, it is requested that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher.

[0003] However, if the discharge lamp is stably lit with the electric power of 25 W at steady time, a desired discharge lamp that satisfies both of the light-emitting efficiency of 78 lm/W or higher and the luminous flux maintenance factor of 90% or higher at lamp life 3000 hours has not been obtained.

[0004] An object of the exemplary embodiments is to provide a discharge lamp that satisfies light-emitting efficiency necessary at steady time and satisfies a luminous flux maintenance factor necessary even after a long time elapses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 is a sectional view showing the vicinity of a light-emitting section of a discharge lamp according to an embodiment.
FIG. 2 is a sectional view showing the discharge lamp.
FIG. 3 is a diagram showing the discharge lamp.
FIG. 4 is a diagram showing a measurement result of light-emitting efficiency and a luminous flux maintenance factor of the discharge lamp.
FIG. 5 is a diagram showing a measurement result of light-emitting efficiency and a luminous flux maintenance factor of the discharge lamp.
FIG. 6 is a diagram showing a measurement result of light-emitting efficiency and a luminous flux maintenance factor of the discharge lamp.
FIG. 7 is a sectional A-A arrow view taken along an alternate long and short dash line A-A of the discharge lamp shown in FIG. 2.
FIG. 8 is a sectional A-A arrow view taken along the alternate long and short dash line A-A of the discharge lamp shown in FIG. 2.

DETAILED DESCRIPTION

[0006] In general, according to one embodiment, there is provided a discharge lamp 1 including: a light-emitting section 10 including a discharge space 13 on the inside; a pair of sealing sections 20 provided at both end portions 12 of the light-emitting section 10; and a pair of electrodes 30, one ends of which are disposed on the insides of the sealing sections 20 and the other ends of which are disposed to be opposed to each other in the discharge space 13. The light-emitting section 10 has maximum thickness in a center portion 11 in a direction in which the pair of electrodes 30 extends. The inner circumferential surface of the light-emitting section 10 includes a pair of taper surfaces 10a expanding in an inner diameter from the respective both end portions 12 toward the center portion 11 of the light-emitting section 10 in the direction in which the pair of electrodes 30 extends and a cylindrical side circumferential surface 10b contiguous to the pair of taper surfaces 10a and extending along the direction in which the pair of electrodes 30 extends. Length IL (mm) of the side circumferential surface 10b in the direction in which the pair of electrodes 30 extends, an inner diameter ID (mm) in the side circumferential surface 10b of the light-emitting section 10, and maximum thickness t (mm) of the light-emitting section 10 satisfy the following Expression 1:

$$5.8 \leq (IL \times ID)/t \leq 9.8 \qquad (1)$$

[0007] The discharge lamp 1 according to the embodiment explained below is stably lit with electric power of 18 to 30 W.

[0008] The discharge lamp 1 satisfies the following Expression 2:

$$6.2 \leq (IL \times ID)/t \leq 9.4 \quad (2)$$

[0009] In the discharge lamp 1, the length IL of the side circumferential surface 10b in the direction in which the pair of electrodes 30 extends is 2.5 mm or more and 6.0 mm or less.

[0010] In the discharge lamp 1, the inner diameter ID in the side circumferential surface 10b of the light-emitting section 10 is 2.0 mm or more and 2.6 mm or less.

[0011] In the discharge lamp 1, the maximum thickness t of the light-emitting section 10 is 1.0 mm or more and 2.0 mm or less.

[0012] In the discharge lamp 1, the volume of the discharge space 13 is 15 mm^3 or more and 30 mm^3 or less.

[0013] In the discharge lamp 1, the sealing section 20 includes a horizontal section 21 extending in the direction in which the pair of electrodes 30 extends and a taper section 22 reduced in width and thickness from the horizontal section 21 toward the end portion 12 of the light-emitting section 10 and contiguous to the end portion 12 of the light-emitting section 10.

[0014] In the discharge lamp 1, a value L1/L2 of a ratio of length L1 (mm) of the taper section 22 and length L2 (mm) of the horizontal section 21 in the direction in which the pair of electrodes 30 extends is 0.6 or more and 4.0 or less.

[0015] In the discharge lamp 1, a value W2/W1 of a ratio of width W1 (mm) of the horizontal section 21 and width W2 (mm) of the taper section 22 is 0.7 or more and 0.95 or less.

Embodiment

[0016] First, the discharge lamp 1 according to the embodiment is explained with reference to the drawings. FIGS. 1 and 2 are sectional views showing the discharge lamp 1 according to the embodiment.

[0017] The discharge lamp 1 is, for example, a discharge lamp shown in FIG. 3 and can be used as a light source for a headlight of an automobile. As shown in FIG. 3, the discharge lamp 1 includes the light-emitting section 10 inside an elongated substantially cylindrical outer tube 50 attached to a socket 6. The outer tube 50 is attached to the socket 6 by, for example, attaching a metal band 61 to the outer circumferential surface of the outer tube 50 and gripping the metal band 61 with four tongue pieces 62 made of metal formed to project from the socket 6. Note that, if the discharge lamp 1 is used as an automobile head light, the discharge lamp 1 is lit in a state in which the tube axis of the outer tube 50 is substantially horizontal.

[0018] The light-emitting section 10 has a substantially elliptical external shape when viewed from the tube axis direction and has, in the center in the longitudinal direction, the convex center portion 11 having maximum thickness. That is, the center in the longitudinal direction of the light-emitting section 10 has an external shape like a convex substantially ellipsoidal. The light-emitting section 10 has the maximum thickness t, which is maximum thickness in the light-emitting section 10, in the center portion 11. A length in the longitudinal direction of the light-emitting section 10 is D1 (hereinafter referred to as "spherical body length D1"). The light-emitting section 10 has a shape reduced in an outer diameter toward both the end portions 12 in the longitudinal direction. The light-emitting section 10 includes the discharge space 13 on the inside. Note that, in the discharge space 13, a discharge medium including metal halide and inert gas (rare gas) is encapsulated. Details of the discharge space 13 are explained below.

[0019] As shown in FIG. 1, the pair of sealing sections 20 is respectively contiguous to both the end portions 12 in the longitudinal direction of the light-emitting section 10. For example, the light-emitting section 10 and the sealing sections 20 are integrally formed of a material having heat resistance and translucency such as quartz glass and are referred to as an inner tube. Such a pair of sealing sections 20 can be formed using a pinch seal method. The sealing section 20 is formed in a bar shape extending along the longitudinal direction of the light-emitting section 10. Specifically, the sealing section 20 includes the horizontal section 21 having substantially the same width and substantially the same thickness along the longitudinal direction and the taper section 22 reduced in width and thickness from the horizontal section 21 toward the end portion 12 of the light-emitting section 10. The sealing section 20 is contiguous to the end portion 12 of the light-emitting section 10 via the taper section 22.

[0020] One ends of the pair of electrodes 30 are respectively sealed by the sealing sections 20 and the other ends are disposed to be opposed to each other in the discharge space 13 of the light-emitting section 10. That is, the one ends of the pair of electrodes 30 are disposed in the sealing sections 20 and the other ends are disposed to project to the discharge space 13 passing through the taper sections 22 of the sealing sections 20 and the end portions 12 of the light-emitting section 10. The pair of electrodes 30 are disposed with both the other ends spaced apart a distance D2 (hereinafter referred to as "inter-electrode distance D2") and opposed to each other in the discharge space 13 of the light-emitting section 10. The electrode 30 is, for example, a bar-like member configured from so-called thoriated tungsten obtained by doping thorium oxide in tungsten. Note that the shape of the electrode 30 is not limited to a straight bar shape, the diameter of which is substantially fixed in the tube axis direction and may be a non-straight bar shape, the diameter of the distal end portion of which is larger than the diameter of the proximal end portion thereof, a spherical shape at the distal end, or a shape, one electrode diameter of which is different from the other electrode diameter thereof, like a direct-current lighting type. An electrode material may be pure tungsten, toped tungsten, rhenium tungsten, or the like.

[0021] As shown in FIG. 2, the light-emitting section 10 and the sealing sections 20 are disposed in the outer tube 50 such that the direction in which the pair of electrodes 30 extends is along the tube axis direction of the outer tube 50. Specifically, the light-emitting section 10 and the sealing sections 20 are connected to the outer tube 50 via boundary sections 23 to thereby be fixed in positions in the outer tube 50 and disposed in the outer tube 50. Connection of the outer tube 50 and the sealing section 20 is performed by, for example, welding the outer tube 50 to the vicinity of the sealing section 20. Gas is encapsulated in a closed space (hereinafter referred to as "space in the outer tube 50") formed between the light-emitting section 10 and the sealing sections 20 and the outer tube 50. The gas encapsulated in the space in the outer tube 50 can be, for example, one kind of gas selected out of neon, argon, xenon, and nitrogen or mixed gas of neon, argon, xenon, and nitrogen. Note that the outer tube 50 is desirably configured from a material having a coefficient of thermal expansion close to the coefficient of thermal expansion of the light-emitting section 10 and the sealing sections 20 and having an ultraviolet ray blocking property. For example, quartz glass added with oxide of titanium, cerium, or aluminum may be used.

[0022] A pair of metal foils 40 is provided in the horizontal sections 21 of the sealing sections 20. One ends of the electrodes 30 are welded to be placed on end portions on the light-emitting section 10 side of the metal foils 40. The metal foil 40 is a thin plate-like member made of, for example, molybdenum.

[0023] One ends of a pair of lead wires 60 are placed on end portions on the opposite side of the light-emitting section 10 side of the metal foils 40. The other end of one lead wire 60 (on the right side in FIG. 2) extends to the outside of the outer tube 50 passing through the sealing section 20. For example, one end of an L-shaped support wire 63 made of nickel is connected to the lead wire 60 by laser welding. Note that the support wire 63 is electrically connected to a not-shown side terminal or the like provided in the socket 6. The other end of the other lead wire 60 (on the left side in FIG. 2) projects from the sealing section 20 and electrically connected to a not-shown bottom terminal or the like provided in the bottom of the socket 6.

[0024] The light-emitting section 10 includes the pair of taper surfaces 10a, which is inner circumferential surfaces expanding in an inner diameter from the respective both end portions 12 toward the center portion of the light-emitting section 10 in the direction in which the pair of electrodes 30 extends and the side circumferential surface 10b, which is a cylindrical inner circumferential surface contiguous to the pair of taper surfaces 10a and extending along the direction in which the pair of electrodes 30 extends. That is, the light-emitting section 10 includes the discharge space 13 formed by the pair of taper surfaces 10a and the side circumferential surface 10b.

[0025] In the following explanation, the length of the side circumferential surface 10b of the light-emitting section 10 in the direction in which the pair of electrodes 30 extends is represented as straight length IL (mm) and the inner diameter on the side circumferential surface 10b of the light-emitting section 10 is represented as light-emitting-section inner diameter ID (mm).

[0026] A relation between the straight length IL (mm), the light-emitting-section inner diameter ID (mm), and the maximum thickness t (mm) and light-emitting efficiency (lm/W) and a luminous flux maintenance factor (%) is explained with reference to FIGS. 4 to 6. FIG. 4 shows a measurement result of light-emitting efficiency and a luminous flux maintenance factor obtained when the straight length IL, the light-emitting-section inner diameter ID, and the maximum thickness t are changed when the lamp is lit with 25 W. Note that, in this measurement, a luminous flux of the discharge lamp 1 was measured using a spectroradiometer SR-3 (manufactured by Topcon Corporation) and electric power supplied to the discharge lamp 1 was measured using a digital power meter WT-210 (manufactured by Yokogawa Meters & Instruments Corporation).

[0027] The light-emitting efficiency and the luminous flux maintenance factor are explained. The light-emitting efficiency is measured by setting the discharge lamp 1 in an integrating sphere having a diameter of 1 m and lighting the discharge lamp 1. The light-emitting efficiency is derived from the following Expression 3 for dividing a total luminous flux (lm) of the discharge lamp 1 during steady lighting of the discharge lamp 1 by electric power (W) supplied to the discharge lamp 1:

$$\text{Light-emitting efficiency (lm/W)} = \text{total luminous flux (lm)} / \text{electric power (W)} \qquad (3)$$

[0028] Concerning the luminous flux maintenance factor, like the light-emitting efficiency, the total luminous flux (lm) of the discharge lamp 1 during the steady lighting of the discharge lamp 1 is measured. The luminous flux maintenance factor is derived from the following Expression 4 for dividing the total luminous flux (lm) after the elapse of x hours (i.e., lamp life x hours) from the lighting start by the total luminous flux (lm) at the lighting start (i.e., lamp life 0 hours) and multiplying the quotient with 100:

$$\text{Luminous flux maintenance factor at lamp life x hours (\%)} = \text{total luminous flux at lamp life x hours (lm)} / \text{total luminous flux at lamp life 0 hours (lm)} \times 100 \qquad (4)$$

[0029] Other items in this measurement are explained below. First, the metal halide encapsulated in the discharge space 13 of the light-emitting section 10 is configured from a mixture of scandium iodide (ScI_3), sodium iodide (NaI), zinc iodide (ZnI_2), and indium bromide (InBr). An encapsulation amount ratio of the metal halides was set to ScI_3:NaI:ZnI_2:InBr=1.00:1.10:0.11:0.003 in a weight ratio. A total amount of the metal halide encapsulated in the discharge space 13 of the light-emitting section 10 was set to 0.2 mg. The rare gas encapsulated in the discharge space 13 of the light-emitting section 10 was encapsulated at 13.0 atm at the room temperature (25°C) using xenon.

[0030] As the electrode 30 in this measurement, a straight bar-like electrode having substantially fixed diameter (hereinafter referred to as "electrode diameter D3") in the tube axis direction was used. The electrode diameter D3 of the electrode 30 was set to 0.28 mm. The inter-electrode distance D2 of the pair of electrodes 30 was set to 3.9 mm. The spherical body length D1 of the light-emitting section 10 was set to 7.75 mm. As the gas encapsulated in the space in the outer tube 50, argon was used. The gas pressure of the space in the outer tube 50 was set to 0.1 atm or less at the room temperature (25°C).

[0031] A relation between the horizontal section 21 and the taper section 22 in the sealing section 20 in this measurement is explained. FIG. 7 is a diagram showing the length L2 (mm) of the horizontal section 21 and the length L1 (mm) of the taper section 22 in the direction in which the pair of electrodes 30 extends. In the sealing section 20 in this measurement, the length L2 of the horizontal section 21 and the length L1 of the taper section 22 were set such that a ratio of the length L1 and the length L2 was L1/L2=2.3. FIG. 8 is a diagram showing the width W1 (mm) of the horizontal section 21 and the width W2 (mm) of the taper section 22. Note that the width W2 of the taper section 22 was set with reference to the width of the taper section 22 in a portion apart from a part of the light-emitting section 10 contiguous to the end portion 12 by a distance DN in the direction in which the pair of electrodes 30 extends. Note that, in this embodiment, the distance DN was set to 2.0 mm. In the sealing section 20 in this measurement, the width W1 of the horizontal section 21 and the width W2 of the taper section 22 were set such that a ratio of the width W2 and the width W1 was W2/W1=0.93.

[0032] As a result of performing the measurement on the basis of the above specification, measurement results shown in FIGS. 4 to 6 were obtained. In general, the discharge lamp 1 shows a tendency that the light-emitting efficiency is improved as the temperature of the light-emitting section 10 rises but the luminous flux maintenance factor is deteriorated if the temperature of the light-emitting section 10 is too high. On the other hand, the discharge lamp 1 shows a tendency that the luminous flux maintenance factor is improved as the temperature of the light-emitting section 10 drops but the light-emitting efficiency is deteriorated if the temperature of the light-emitting section 10 is too low. If the discharge lamp 1 is lit, the temperature of the light-emitting section 10 rises. First, if the discharge lamp 1 is lit, an arc occurs in the discharge space 13 of the light-emitting section 10. The arc is unevenly distributed to one side in the latitudinal direction of the light-emitting section 10 in the discharge space 13. For example, if the discharge lamp 1 shown in FIG. 2 is attached in a state in which the upper end side of the light-emitting section 10 faces up, since the arc occurs to curve upward between the electrodes 30, the temperature on the upper end side of the light-emitting section 10 shown in FIG. 2 is the highest in the light-emitting section 10. Therefore, in order to improve both of the light-emitting efficiency and the luminous flux maintenance factor of the discharge lamp 1, it is considered desirable that the external shape of the light-emitting section 10 is a substantially elliptical shape when viewed from the tube axis direction and is a shape, the center in the longitudinal direction of which is the thickest.

[0033] A value obtained by multiplying together the straight length IL (mm) and the light-emitting-section inner diameter ID (mm) indicates the area of the portion of the side circumferential surface 10b of the light-emitting section 10 in FIG. 1 (in the following explanation, IL×ID is referred to as light-emitting area IL×ID). A decrease in the light-emitting area IL×ID leads to a decrease in the volume of the discharge space 13. If the volume of the discharge space 13 decreases, the temperature of the light-emitting section 10 rises. This is considered to be because, if the light-emitting-section inner diameter ID or the straight length IL decreases, since the distance between the arc generated between the electrodes 30 and the inner circumferential surface of the light-emitting section 10 decreases, the temperature of the light-emitting section 10 rises.

[0034] On the other hand, an increase in the light-emitting area IL×ID leads to an increase in the volume of the discharge space 13. If the volume of the discharge space 13 increases, the temperature of the light-emitting section 10 drops. This is considered to be because, if the light-emitting-section inner diameter ID or the straight length IL increases, since the distance between the arc generated between the electrodes 30 and the inner circumferential surface of the light-emitting section 10 increases, the temperature of the light-emitting section 10 drops.

[0035] If the maximum thickness t decreases, the temperature of the light-emitting section 10 rises. On the other hand, if the maximum thickness t increases, the temperature of the light-emitting section 10 drops.

[0036] According to the measurement result shown in FIG. 4, a correlation is recognized in which, if the value of (IL×ID)/t decreases, the light-emitting efficiency is deteriorated and the luminous flux maintenance factor is improved. On the other hand, a correlation is recognized in which, if the value of (IL×ID)/t increases, the light-emitting efficiency is improved and the luminous flux maintenance factor is deteriorated. Therefore, in the measurement result obtained by varying the numerical value of (IL×ID)/t, it is recognized that the light-emitting efficiency and the luminous flux maintenance factor are in a tradeoff relation.

[0037] In FIG. 4, if the light-emitting efficiency is 78 lm/W or higher, a column of "determination" of "light-emitting efficiency" is "A". If the light-emitting efficiency is lower than 78 lm/W, the column of "determination" of "light-emitting efficiency" is "C". If the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher, a column of "determination" of "luminous flux maintenance factor" is "A". If the luminous flux maintenance factor at lamp life 3000 hours is lower than 90%, the column of "determination" of "luminous flux maintenance factor" is "C". If the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher, a column of "overall determination" is "A" or "S". In other cases, the column of "overall determination" is "C". That is, "C" of the item of "overall determination" means a lamp that shows an unsatisfactory characteristic, "A" means a lamp that shows a satisfactory characteristic, and "S" means a lamp that shows a more satisfactory characteristic among lamps that show the satisfactory characteristic.

[0038] As shown in FIG. 4, a measurement result was obtained that, if (IL×ID)/t is 5.8 or more and 9.8 or less, the discharge lamp 1 satisfies the condition that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher. That is, the measurement result indicates that the discharge lamp 1 in which (IL×ID)/t is 5.8 or more and 9.8 or less satisfies the light-emitting efficiency necessary at steady time and satisfies the luminous flux maintenance factor necessary even after a long time elapses. Note that, in the example shown in FIG. 4, taking into account manufacturing variation and the like, a range equal to the target value (78 lm/W) of the light-emitting efficiency and the target value (90%) of the luminous flux maintenance factor is represented as "A" and a range in which the other conditions are satisfied is represented as "S".

[0039] As a result, the measurement result shown in FIG. 4 indicates that, for the discharge lamp 1 to satisfy the light-emitting efficiency necessary at steady time and satisfy the luminous flux maintenance factor necessary even after a long time elapses, (IL×ID)/t is suitably 6.2 or more and 9.4 or less. That is, it is recognized that, in the discharge lamp 1 that satisfies the condition that (IL×ID)/t is 6.2 or more and 9.4 or less, the temperature of the light-emitting section 10 during lighting is temperature suitable for satisfying both of the light-emitting efficiency of 78 lm/W or higher and the luminous flux maintenance factor of 90% or higher at lamp life 3000 hours.

[0040] FIG. 5 shows a measurement result obtained by fixing the straight length IL and the light-emitting-section inner diameter ID (i.e., fixing the light-emitting area IL×ID) in order to indicate that the light-emitting efficiency and the luminous flux maintenance factor change according to fluctuation in the maximum thickness t. Note that the measurement result shown in FIG. 5 is a measurement result for indicating influence that occurs if only the maximum thickness t is varied. Therefore, the overall determination is "A" in all the cases if the condition that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher is satisfied.

[0041] As shown in FIG. 5, if the maximum thickness t decreases, the light-emitting efficiency is improved and the luminous flux maintenance factor is deteriorated. On the other hand, if the maximum thickness t increases, the light-emitting efficiency is deteriorated and the luminous flux maintenance factor is improved. According to the measurement result shown in FIG. 5, it is recognized that the light-emitting efficiency and the luminous flux maintenance factor change according to fluctuation in the maximum thickness t. The measurement result shown in FIG. 5 indicates that, even if the straight length IL and the light-emitting-section inner diameter ID are fixed and the maximum thickness t is changed, if (IL×ID)/t is 5.8 or more and 9.8 or less, the discharge lamp 1 satisfies the condition that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher.

[0042] FIG. 6 shows a measurement result obtained by fixing the maximum thickness t in order to indicate that the light-emitting efficiency and the luminous flux maintenance factor change according to fluctuation in the light-emitting area IL×ID. Note that the measurement result shown in FIG. 6 is a measurement result for indicating influence that occurs when only the light-emitting area IL×ID is varied. Therefore, the overall determination is "A" in all the cases if the condition that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher is satisfied.

[0043] As shown in FIG. 6, if the light-emitting area IL×ID decreases, the light-emitting efficiency is improved and the luminous flux maintenance factor is deteriorated. On the other hand, if the light-emitting area IL×ID increases, the light-emitting efficiency is deteriorated and the luminous flux maintenance factor is improved. According to the measurement result shown in FIG. 6, it is recognized that the light-emitting efficiency and the luminous flux maintenance factor change according to fluctuation in the light-emitting area IL×ID. The measurement result shown in FIG. 6 indicates that, even if the maximum thickness t is fixed and the light-emitting area IL×ID is changed, if (IL×ID)/t is 5.8 or more and 9.8 or less, the discharge lamp 1 satisfies the condition that the light-emitting efficiency is 78 lm/W or higher and the luminous flux maintenance factor at lamp life 3000 hours is 90% or higher.

[0044] Note that the discharge lamp 1 suitably satisfies the above Expression 1 and is stably lit with low electric power of 18 to 30 W. The straight length IL suitably satisfies the above Expression 1 and is 2.5 mm or more and 6.0 mm or less. The light-emitting-section inner diameter ID suitably satisfies the above Expression 1 and is 2.0 mm or more and 2.6 mm or less. The volume of the discharge space 13 of the light-emitting section 10 suitably satisfies the above Expression 1 and is 15 mm^3 or more and 30 mm^3 or less.

[0045] In the measurement shown in FIGS. 4 and 5, in the sealing section 20, the length L2 of the horizontal section 21 and the length L1 of the taper section 22 were set such that a ratio of the length L1 and the length L2 was L1/L2=2.3. In the sealing section 20, concerning the length L2 of the horizontal section 21 and the length L1 of the taper section 22, L1/L2 is suitably 0.6 or more and 4.0 or less. Consequently, it is possible to suppress a crack leak from occurring in the sealing section 20.

[0046] In the measurement shown in FIGS. 4 to 5, in the sealing section 20, the width W1 of the horizontal section 21 and the width W2 of the taper section 22 were set such that a ratio of the width W2 and the width W1 was W2/W1=0.93. In the sealing section 20, concerning the width W1 of the horizontal section 21 and the width W2 of the taper section 22, W2/W1 is suitably 0.70 or more and 0.95 or less. Consequently, it is possible to suppress a crack leak from occurring in the sealing section 20.

[0047] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

1. A discharge lamp comprising:

a light-emitting section including a discharge space on the inside;
a pair of sealing sections provided at both end portions of the light-emitting section; and
a pair of electrodes, one ends of which are disposed on insides of the sealing sections and the other ends of which are disposed to be opposed to each other in the discharge space, wherein
the light-emitting section has maximum thickness in a center portion in a direction in which the pair of electrodes extends,
an inner circumferential surface of the light-emitting section includes a pair of taper surfaces expanding in an inner diameter from the respective both end portions toward the center portion of the light-emitting section in the direction in which the pair of electrodes extends and a cylindrical side circumferential surface contiguous to the pair of taper surfaces and extending along the direction in which the pair of electrodes extends, and
length IL (mm) of the side circumferential surface in the direction in which the pair of electrodes extends, an inner diameter ID (mm) in the side circumferential surface of the light-emitting section, and maximum thickness t (mm) of the light-emitting section satisfy a following Expression 1:

$$5.8 \leq (IL \times ID)/t \leq 9.8 \qquad (1)$$

2. The lamp according to claim 1, wherein the discharge lamp is stably lit with electric power of 18 to 30 W.

3. The lamp according to claim 1 or 2, wherein the discharge lamp satisfies a following Expression 2:

$$6.2 \leq (IL \times ID)/t \leq 9.4 \qquad (2)$$

4. The lamp according to any one of claims 1 to 3, wherein the length IL of the side circumferential surface in the direction in which the pair of electrodes extends is 2.5 mm or more and 6.0 mm or less.

5. The lamp according to any one of claims 1 to 4, wherein the inner diameter ID in the side circumferential surface of the light-emitting section is 2.0 mm or more and 2.6 mm or less.

6. The lamp according to any one of claims 1 to 5, wherein the maximum thickness t of the light-emitting section is 1.0 mm or more and 2.0 mm or less.

7. The lamp according to any one of claims 1 to 6, wherein a volume of the discharge space is 15 mm^3 or more and 30 mm^3 or less.

8. The lamp according to any one of claims 1 to 7, wherein the sealing section includes a horizontal section extending in the direction in which the pair of electrodes extends and a taper section reduced in width and thickness from the horizontal section toward the end portion of the light-emitting section and contiguous to the end portion of the light-emitting section.

9. The lamp according to claim 8, wherein a value L1/L2 of a ratio of length L1 (mm) of the taper section and length L2 (mm) of the horizontal section in the direction in which the pair of electrodes extends is 0.6 or more and 4.0 or less.

10. The lamp according to claim 8 or 9, wherein a value W2/W1 of a ratio of width W1 (mm) of the horizontal section and width W2 (mm) of the taper section is 0.7 or more and 0.95 or less.

FIG.1

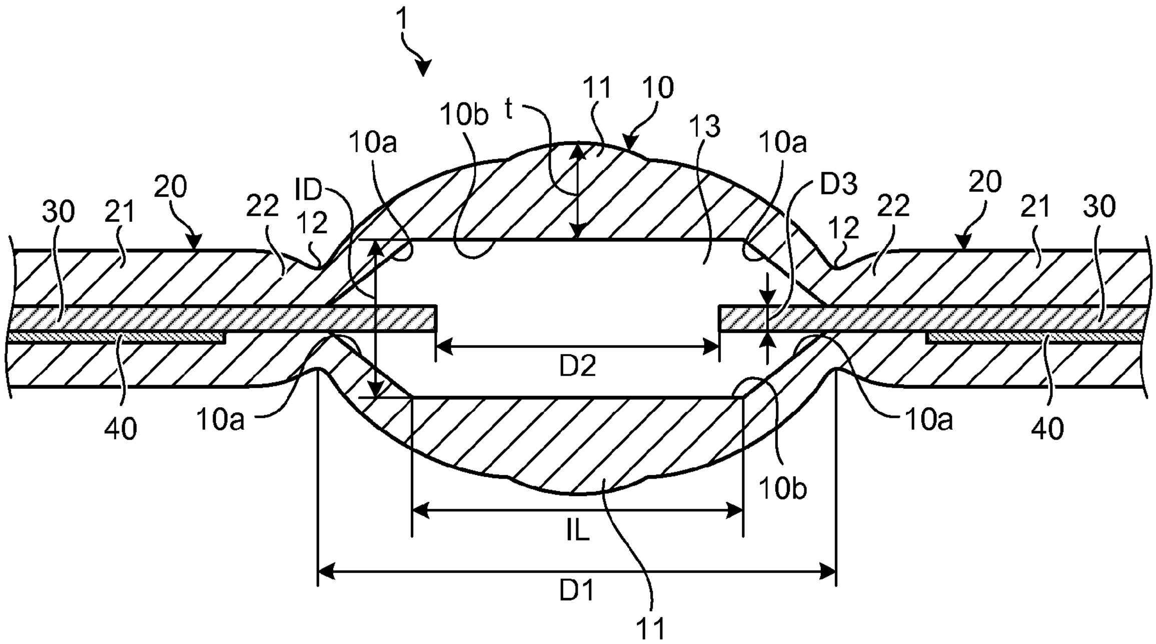

1
t
11
10
10b
13
10a
10a
20
30
21
22
ID
12
D3
12
22
20
21
30
D2
40
10a
10a
40
10b
IL
D1
11

FIG.2

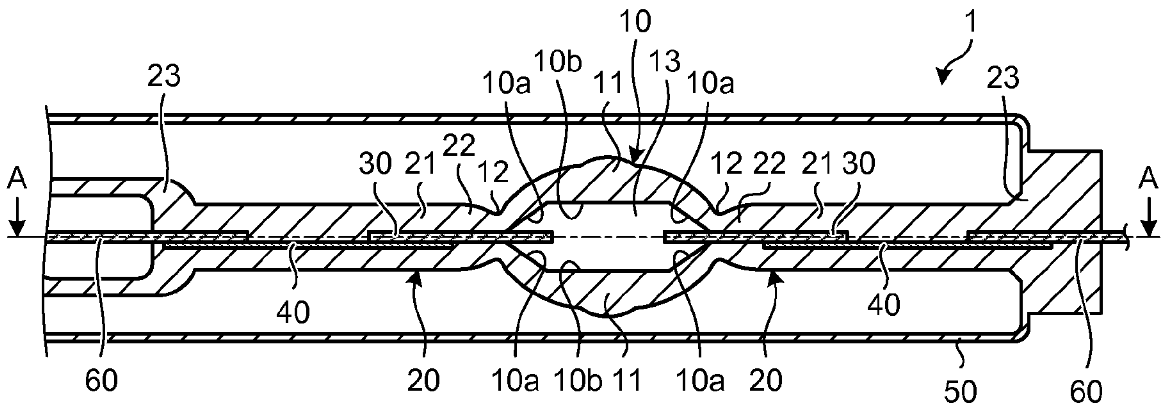

10
1
10b
13
23
10a
11
10a
23
A
30
21
22
12
12
22
21
30
A
40
40
60
20
10a
10b
11
10a
20
50
60

FIG.3

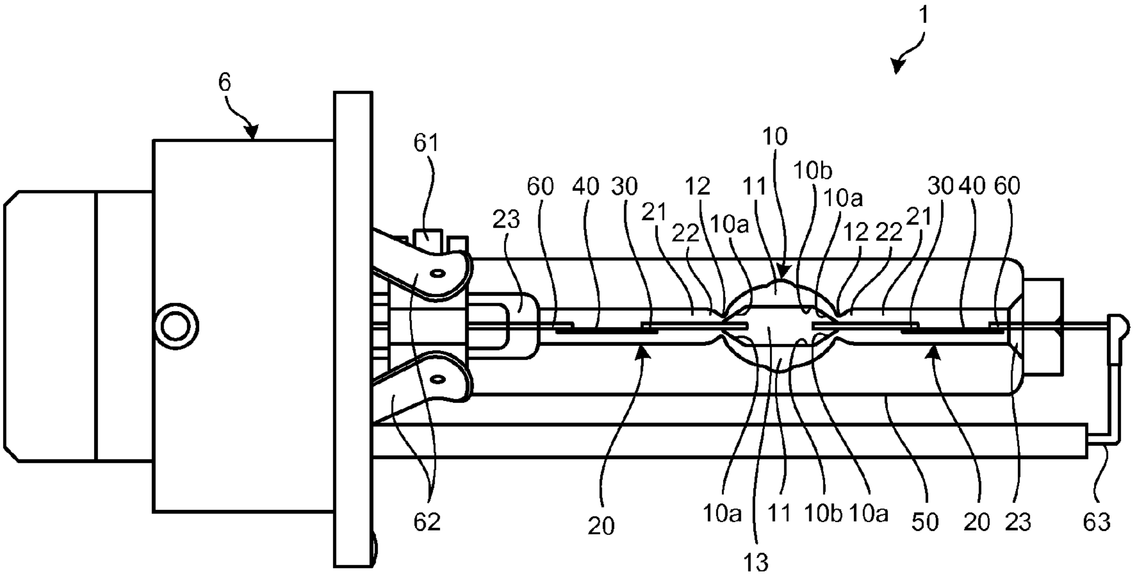

1
6
10
61
60 40 30
12 11 10b
10a
30 40 60
23
21
22 10a
12 22
21
62
20
10a 11 10b 10a
13
50 20 23
63

FIG.4

MEASUREMENT RESULT OF LIGHT-EMITTING EFFICIENCY AND LUMINOUS FLUX MAINTENANCE FACTOR

IL	ID	t	(IL×ID)/t	LIGHT-EMITTING EFFICIENCY (POWER 25 W)		LUMINOUS FLUX MAINTENANCE FACTOR (3000 HOURS)		OVERALL
(mm)	(mm)	(mm)		(lm/W)	DETERMI-NATION	(%)	DETERMI-NATION	DETERMI-NATION
2.8	2.10	1.85	3.2	70	C	95	A	C
2.9	2.15	1.70	3.7	72	C	94	A	C
2.9	2.10	1.50	4.1	72	C	93	A	C
3.5	2.15	1.65	4.6	72	C	94	A	C
3.5	2.20	1.55	5.0	73	C	92	A	C
3.6	2.25	1.50	5.4	75	C	93	A	C
3.8	2.30	1.50	5.8	78	A	93	A	A
3.8	2.30	1.40	6.2	80	A	93	A	S
4.0	2.30	1.40	6.6	81	A	91	A	S
4.0	2.35	1.35	7.0	83	A	92	A	S
4.3	2.35	1.35	7.5	83	A	92	A	S
4.5	2.35	1.35	7.8	84	A	93	A	S
4.7	2.35	1.35	8.2	86	A	91	A	S
4.9	2.35	1.35	8.5	86	A	92	A	S
5.0	2.35	1.30	9.0	87	A	91	A	S
5.1	2.40	1.30	9.4	87	A	91	A	S
5.2	2.45	1.30	9.8	88	A	90	A	A
5.2	2.45	1.25	10.2	89	A	88	C	C
5.3	2.40	1.20	10.6	89	A	87	C	C
5.3	2.50	1.20	11.0	89	A	87	C	C
5.4	2.40	1.15	11.3	90	A	88	C	C
5.5	2.45	1.15	11.7	90	A	86	C	C
5.5	2.50	1.10	12.5	91	A	84	C	C

FIG.5

MEASUREMENT RESULT OBTAINED BY FIXING STRAIGHT LENGTH IL AND LIGHT-EMITTING-SECTION INNER DIAMETER ID

IL	ID	t	(IL×ID)/t	LIGHT-EMITTING EFFICIENCY (POWER 25 W)		LUMINOUS FLUX MAINTENANCE FACTOR (3000 HOURS)		OVERALL
(mm)	(mm)	(mm)		(lm/W)	DETERMI-NATION	(%)	DETERMI-NATION	DETERMI-NATION
4.5	2.35	1.95	5.4	74	C	92	A	C
4.5	2.35	1.90	5.6	76	C	93	A	C
4.5	2.35	1.82	5.8	78	A	93	A	A
4.5	2.35	1.75	6.0	79	A	92	A	A
4.5	2.35	1.70	6.2	79	A	91	A	A
4.5	2.35	1.65	6.4	79	A	92	A	A
4.5	2.35	1.15	9.2	86	A	92	A	A
4.5	2.35	1.12	9.4	86	A	92	A	A
4.5	2.35	1.10	9.6	87	A	91	A	A
4.5	2.35	1.08	9.8	89	A	91	A	A
4.5	2.35	1.06	10.0	91	A	88	C	C
4.5	2.35	1.04	10.2	92	A	87	C	C

FIG.6

MEASUREMENT RESULT OBTAINED BY FIXING MAXIMUM THICKNESS t

IL	ID	t	(IL×ID)/t	LIGHT-EMITTING EFFICIENCY (POWER 25 W)		LUMINOUS FLUX MAINTENANCE FACTOR (3000 HOURS)		OVERALL
(mm)	(mm)	(mm)		(lm/W)	DETERMI-NATION	(%)	DETERMI-NATION	DETERMI-NATION
3.1	2.32	1.32	5.4	90	A	87	C	C
3.1	2.37	1.32	5.6	90	A	87	C	C
3.3	2.33	1.32	5.8	87	A	90	A	A
3.3	2.38	1.32	6.0	87	A	93	A	A
3.5	2.35	1.32	6.2	87	A	92	A	A
3.5	2.40	1.32	6.4	86	A	92	A	A
4.9	2.48	1.32	9.2	82	A	93	A	A
5.1	2.44	1.32	9.4	80	A	92	A	A
5.1	2.48	1.32	9.6	79	A	93	A	A
5.3	2.44	1.32	9.8	79	A	94	A	A
5.3	2.50	1.32	10.0	76	C	93	A	C
5.5	2.45	1.32	10.2	73	C	93	A	C

FIG.7

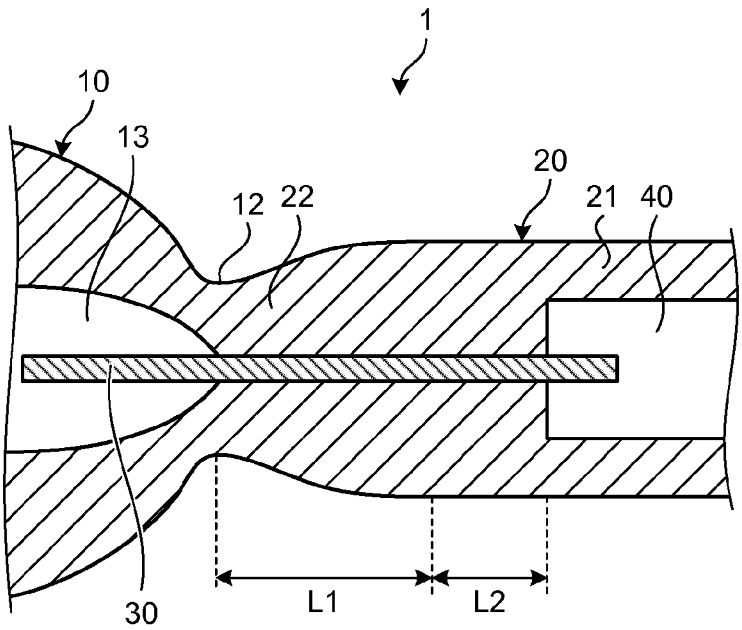


FIG.8