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(54) **LIGHTING DEVICE**

(57) A lighting device that can improve its light output ratio and heat release properties is to be provided. A lighting device according to an embodiment includes: a globe having an opening at one end and a hollow inside; a base housed in the globe; a light source including at least one LED provided on the base, the light source being housed in the globe; a light guide member configured to cover a light-emitting surface of the light source, the light guide member having optical transparency, the light guide member being housed in the globe; a columnar support configured to support the base, the columnar support being housed in the globe and being located on the opposite side from the light source and the light guide member; a radiation layer configured to radiate heat, the radiation layer being provided on a surface of the columnar support; a globe connector connected to the columnar support at the one end of the globe; a cap connector connected to the globe connector; a bayonet cap configured to supply electrical power to the light source, the bayonet cap being connected to the cap connector; and a wiring line configured to electrically connect the bayonet cap and the light source.

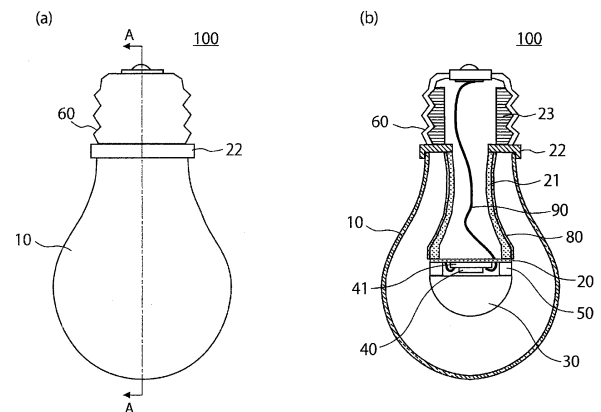


FIG. 1

DescriptionFIELD

5 **[0001]** Embodiments of the present invention relate to lighting devices.

BACKGROUND

10 **[0002]** In a lighting device using an LED (Light-Emitting Diode), the LED that emits light is normally placed on a surface of a base, and a spherical globe is provided to cover the LED. With this structure, light from the LED is diffused and released to the outside. In such a lighting device, heat from the LED is transferred to the base, and is then released to the outside from the other surface (heat releasing surface) of the base in contact with external air.

15 **[0003]** A lighting device using an LED is expected to realize a scale indicating substantially the same light distribution angle or degree of spread of light emitted from the LED as that of a lighting device using a conventional filament or the like, such as an incandescent bulb, a scale indicating a total flux or a degree of luminance of light emitted from the LED, a scale of indicating transparency or the proportion of the surface through which light from the lighting device passes through, and the same position of the light source as that in an incandescent bulb. In an incandescent bulb, light is emitted from the center of the globe in which a filament is located, and the light source is located at the center of the globe.

20 **[0004]** In a lighting device using an LED, so as to widen the light distribution angle, the area of the outer surface of the globe through which light is eventually released needs to be increased, and light distribution control needs to be performed so that as much as light emitted forward from the light-emitting surface of the LED will be released in all directions.

25 **[0005]** Also, to increase the total flux, it is necessary to use a higher-output LED, and therefore, the heating value of the LED becomes greater. Heat generated from the LED affects the LED element and the circuit board or the like of a power supply circuit or the like, and as a result, the LED element and the circuit board or the like deteriorate in performance. Therefore, the area of the heat releasing surface of the base needs to be increased, so as to improve the radiation performance of the lighting device.

30 **[0006]** Meanwhile, so as to increase transparency, the proportion of the surface of the globe to the outer surface of the lighting device needs to be increased, and the surface areas of the opaque members provided inside the globe need to be reduced. So as to place the light source at the center of the globe, heat generated from the light source needs to be effectively transferred to the globe and the bayonet cap, and light from the center of the globe should not be blocked by opaque components (JP-A 2012-212682 (KOKAI)).

SUMMARY OF INVENTION

35 Technical Problem

[0007] This embodiment provides a lighting device that is capable of increasing the total flux and widening the light distribution angle.

40 Solution to Problem

45 **[0008]** A lighting device according to an embodiment includes: a globe having an opening at one end and a hollow inside; a base housed in the globe; a light source including at least one LED provided on the base, the light source being housed in the globe; a light guide member configured to cover a light-emitting surface of the light source, the light guide member having optical transparency, the light guide member being housed in the globe; a columnar support configured to support the base, the columnar support being housed in the globe and being located on the opposite side from the light source and the light guide member; a radiation layer configured to radiate heat, the radiation layer being provided on a surface of the columnar support; a globe connector connected to the columnar support at the one end of the globe; 50 a cap connector connected to the globe connector; a bayonet cap configured to supply electrical power to the light source, the bayonet cap being connected to the cap connector; and a wiring line configured to electrically connect the bayonet cap and the light source.

BRIEF DESCRIPTION OF THE DRAWINGS

55 **[0009]**

Figs. 1(a) and 1(b) are diagrams showing a lighting device according to a first embodiment.

Fig. 2 is a diagram showing the lens of the lighting device according to the first embodiment.

Fig. 3 is a diagram showing the columnar support of the lighting device according to the first embodiment.

Fig. 4 is a diagram for explaining the convection inside the globe of the lighting device according to the first embodiment.

Fig. 5 is a diagram for explaining the conditions for obtaining a wide light distribution in the lighting device according to the first embodiment.

Fig. 6 is a cross-sectional view showing a lighting device according to a modification of the first embodiment.

Fig. 7 is a cross-sectional view showing a lighting device according to a second embodiment.

Fig. 8 is a cross-sectional view showing a lighting device according to a third embodiment.

Fig. 9 is a cross-sectional view showing a lighting device according to a fourth embodiment.

Figs. 10(a) and 10(b) are diagrams showing a lighting device according to a fifth embodiment.

DETAILED DESCRIPTION

[0010] The following is a description of embodiments, with reference to the drawings.

(First Embodiment)

[0011] Figs. 1(a) and 1(b) show a lighting device 100 according to a first embodiment. Fig. 1(a) is an outline view of the lighting device 100. Fig. 1(b) is a cross-sectional view of the lighting device 100, taken along the line A-A defined in Fig. 1(a).

[0012] In this embodiment, an example where the lighting device 100 is attached to a socket provided at the ceiling of a room or the like is described. However, the present invention is not limited to this example. The lighting device 100 of the first embodiment includes a globe 10 and a bayonet cap 60. The globe 10 releases light emitted from the later-described light source housed in the globe 10, from the surface to the outside. The bayonet cap 60 serves as an electrical and mechanical connecting portion when the lighting device 100 is fixed to the socket (not shown) with a screw or the like. In this embodiment, the lighting device 100 has a substantially symmetrical shape about the axis or the A-A line. In the description below, this axis will be referred to as the central axis of the lighting device 100.

[0013] As shown in Fig. 1(a), where the lighting device 100 is attached to the socket so that the central axis of the lighting device 100 extends in the direction of gravity, the bayonet cap 60 is located at the upper side of the lighting device 100, and the globe 10 is located at the lower side. When electrical power is supplied to the socket (not shown) from an indoor power supply or the like, light is emitted from the light source provided in the globe 10, and is released to the outside through the surface of the globe 10. In this manner, the lighting device 100 functions as lighting.

[0014] The globe 10 has an opening portion at one end, and this opening portion has a diameter equal to the diameter of the opening portion of the bayonet cap 60. The globe 10 is hollow inside, and has such a shape that the perimeter of the globe 10 in a cross-section perpendicular to the central axis gradually increases in the direction from the opening portion toward the bottom along the central axis of the globe 10, and, once reaching the maximum value, the perimeter of the globe 10 gradually decreases.

[0015] As shown in Fig. 1(b), the lighting device 100 of this embodiment further includes: a plate-like base 20 provided inside the globe 10; a substrate 41 provided on the base 20; a light source 40 provided on the substrate 41; a wiring line 90 electrically connected to the light source 40; a lens (a light guide member) 30 that is located on the light-emitting surface side of the light source 40 and has optical transparency; a lens connector 50 that is provided on the base 20 and secures the lens 30; a columnar support 21 that supports the base 20; a radiation layer 80 provided on the surface of the columnar support 21; a globe connector 22 that is connected to the columnar support 21 and supports the globe 10; and a cap connector 23 that connects the globe connector 22 to the bayonet cap 60.

[0016] The base 20 is a member that has a flat plate-like shape and has the substrate 41 placed thereon. The base 20 conducts heat generated from the light source 40 to the columnar support 21. In the description below, the side of the base 20 facing the light source 40 is defined as the lower surface, and the surface on the opposite side from the lower surface is defined as the upper surface. The base 20 may have a disk-like shape as shown in Fig. 1(b), or may have a polygonal shape, for example. A screw hole, a screw cut, or a hole for connecting to the lens connector 50 and the columnar support 21 is formed in a portion of the base 20. A through hole for allowing the wiring line 90 to extend from the upper surface to the lower surface is also formed in the base 20. Any through hole may not be formed in the base 20. Instead, a hole may be formed in the side surface of the columnar support 21, to allow the wiring line 90 to reach the side of the base 20 facing the substrate 41. The material of the base 20 is a material with excellent heat conductivity, such as an aluminum alloy or a copper alloy.

[0017] The columnar support 21 is a member that is hollow inside, and conducts heat generated from the light source 40 inside, and transfers part of the heat to the globe 10 and the bayonet cap 60. The columnar support 21 has a curved column-like shape as shown in Fig. 1(b), for example. The material of the columnar support 21 is a material with excellent

heat conductivity, such as an aluminum alloy or a copper alloy. The perimeter of the columnar support 21 in a cross-section perpendicular to the central axis of the columnar support 21 varies in the direction toward the bayonet cap 60, and the perimeter is equal to or smaller than the perimeter of the base 20. Here, the perimeter means the outer perimeter.

[0018] The inside of the columnar support 21 is filled with air. However, a refrigerant such as water or fluorocarbon may be sealed in the columnar support 21, and the columnar support 21 may be made to function as a heat pipe, to facilitate heat conduction. Alternatively, a heat pipe may be inserted into the columnar support 21. The radiation layer 80 having excellent heat radiation properties, such as alumite or a coating, is provided on the surface of the columnar support 21. If a material having a low absorptivity with respect to visible light, such as a white-color coating, is used as the radiation layer 80, light loss on the surface of the columnar support 21 can be reduced. Hereinafter, the surface on the hollow side of the columnar support 21 will be referred to as the inner surface, and the surface on the opposite side from this inner surface will be referred to as the outer surface (the surface).

[0019] As the columnar support 21 is provided, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100 can be increased while the light source 40 is maintained at the center of the globe. Also, the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100 becomes higher.

[0020] The globe connector 22 is a member that connects the columnar support 21, the globe 10, and the cap connector 23. Part of the heat generated from the light source 40 propagates to the globe connector 22 via the columnar support 21, and is transferred to the globe 10. The globe connector 22 has a cylindrical shape as shown in Fig. 1(b), for example. A screw hole or the like for integrating with the columnar support 21 or the cap connector 23, or connecting to the columnar support 21 or the cap connector 23 is formed in the globe connector 22. Also, protruding portions or grooves for increasing the area of contact with the globe 10 are formed. The material of the globe connector 22 is a material with excellent heat conductivity, such as an aluminum alloy or a copper alloy. In connecting to the globe 10, an adhesive agent having heat-resisting properties is used, for example. A radiation layer having excellent heat radiation properties, such as alumite or a coating formed through a surface treatment, may be provided on the surface of the globe connector 22 that is in contact with air. If a material having a low absorptivity with respect to visible light, such as a white-color coating, is used as the radiation layer, light loss on the surface of the globe connector 22 can be reduced.

[0021] The cap connector 23 is a member that can be screwed to the bayonet cap 60, and conducts heat generated from the light source 40 to the bayonet cap 60. The cap connector 23 has a cylindrical shape shown in Fig. 1(b), for example, and has opening portions at both ends. A screw hole, a screw cut, or a hole for connecting to the globe connector 22 and the bayonet cap 60 is formed in a portion of the cap connector 23. The material of the cap connector 23 is a material with excellent heat conductivity, such as an aluminum alloy, a copper alloy, ceramic, or a resin. In the description below, the surface of the cap connector 23 on the side of the globe connector 22 is defined as the lower surface, and the surface screwed to the bayonet cap 60 is defined as the side surface.

[0022] As the cap connector 21 releases heat to the bayonet cap 60, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100 can be increased. Also, the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100 becomes higher.

[0023] The lens connector 50 is a member for securing the lens 30 to the substrate 41. The lens connector 50 has a disk-like shape as shown in Fig. 1(b), for example. A protruding portion for pressing the substrate 41 against the base 20 may also be formed in part of the lens connector 50. This protruding portion is formed to avoid the light-emitting surface of the light source 40 and the polar zone (not shown) on the substrate 41. A screw hole, a screw cut, or a hole for connecting to the base 20 may be formed in the lens connector 50. The material of the lens connector 50 is a synthetic resin that excels in rigidity and heat-resisting properties, such as polycarbonate, or a metal such as an aluminum alloy or a copper alloy. In connecting to the lens 30, an adhesive agent having heat-resisting properties is used, for example.

[0024] When securing the lens 30, the lens connector 50 plays the role of a spacer around the substrate 41 and the light source 40. If the lens 30 is made of a resin while the base 20 is made of a metal, the lens connector 50 made of a resin is secured to the base 20 with a screw, and the lens 30 and the lens connector 50 are bonded to each other with an adhesive agent. In this case, adhesion can be achieved without fail, as materials of the same type are bonded to each other, and materials of different types are screwed to each other. It is also possible to form a screw hole directly in the lens 30, and screw the lens 30 to the base 20 with a screw. In this case, however, light reflection or absorption occurs due to the screw hole and the screw, and therefore, it is difficult for the lens 30 to perform light distribution control. With the use of the lens connector 50, secure fixing and easy light distribution control can be realized. In the description below, the surface of the lens connector 50 facing the light source 40 is defined as the lower surface, and the surface on the opposite side from the lower surface is defined as the upper surface.

[0025] The lens 30 is a light transmissive member such as glass or a synthetic resin, and reflects, refracts, and diffuses light on the respective surfaces thereof. Alternatively, light-scattering particles of a scatterer or the like may be sealed in the lens 30, so that the lens 30 has a diffusing function. Fig. 2 is a cross-sectional view of a specific example of this lens 30. The lens 30 includes a diffusion portion 30a, a total reflection portion 30b, and a central portion 30c. The entire surface of the diffusion portion 30a is a diffusing surface. This diffusing surface is formed by sandblasting, for example.

However, the diffusing surface is not necessarily formed by sandblasting, and may be formed with a white coating or the like. The diffusion portion 30a includes a first portion 30a1 of a cylindrical shape, and a second portion 30a2 connected to the first portion 30a1 at joining surfaces. The total reflection portion 30b is covered with the diffusion portion 30a, and the entire surface thereof is a mirrored surface. The central portion 30c is provided at the center of the total reflection portion 30b, and extends along the central axis from the side of the light source 40 to the diffusion portion 30a. Light that enters the central portion 30c from the light source 40 continues to travel straight, and is released to the outside through the diffusion portion 30a.

[0026] The second portion 30a2 of the diffusion portion 30a has an outer surface semispherical about the center point O on the joining surface. This outer surface is similar in shape to the inner surface of the globe 10. That is, the distance between the inner surface of the globe 10 and the outer surface of the diffusion portion 30a is substantially uniform. The center point O is designed to be located at the center of the globe 10. With this, light from the light source 40 is emitted from the center point O or the center of the globe. The largest diameters of the diffusion portion 30a and the total reflection portion 30b are equal to or smaller than the diameter of the opening portion of the globe 10. Accordingly, the lens 30 can be inserted into the globe 10. The material of the lens 30 is preferably acrylic, polycarbonate, cycloolefin polymer, glass, or the like, which has high optical transparency.

[0027] The light source 40 is a component that has one or more light-emitting elements (not shown) such as LEDs mounted on one surface of the plate-like substrate 41, and generates visible light such as white light. In a case where a light-emitting element that emits blue-violet light of 450 nm in wavelength is used, for example, this light-emitting element is covered with a resin material containing a fluorescent substance that absorbs blue-violet light and generates yellow light having a wavelength in the neighborhood of 560 nm, so that the light source 40 generates white light.

[0028] In a case where the substrate 41 is made of a material having a high electrical conductivity, such as a metal, the surface on the opposite side from the surface on which the light source 40 is provided is preferably formed in contact with the surface of the base 20 via a sheet (not shown) that has electrical insulating properties and has an excellent heat conductivity. This is because, so as to transfer heat generated from the light source 40 to the base 20, the contact heat resistance between the light source 40 and the base 20 is preferably as low as possible, and the light source 40 and the base 20 is preferably electrically-insulated from each other, as will be described later. In a case where the substrate 41 is made of a material with a low electrical conductivity, such as ceramic, the above-mentioned insulating sheet is not necessary.

[0029] As indicated by flow lines 71 in Fig. 4, which will be described later, the air in the vicinity of the columnar support 21 becomes lower in density due to heat release from the columnar support 21, and flows in the opposite direction from the direction of gravity. Also, since the low-temperature globe 10 absorbs heat from the air surrounding the globe 10, the air in the vicinity of the globe 10 becomes higher in density, and flows in the forward direction with respect to gravity (or in the same direction as gravity). In this cycle of heat release from the columnar support 21 and heat release to the globe 10 due to the circulating flow, the light source 40 can be efficiently cooled.

[0030] As heat is released from the columnar support 21 to the globe 10 in a noncontact manner by virtue of the convection as described above, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100 can be increased. Also, the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100 becomes higher.

[0031] A power supply circuit (not shown) that supplies electrical power to the light source 40 may be provided in the bayonet cap 60, the cap connector 23, or the columnar support 21. The power supply circuit receives an AC voltage (100 V, for example), converts the AC voltage to a DC voltage, and then applies the DC voltage to the light source 40 through the wiring line 90. In that case, electrical power can be supplied to the light source 40, without the use of any external power supply.

(Description of the Functions)

[0032] Referring to Figs. 1(a) through 4, the functions of the lighting device 100 are now described in detail.

[0033] Fig. 3 is a diagram for explaining the shape of the columnar support 21. Fig. 4 is a diagram for explaining the natural convection in the globe.

[0034] In a situation where the bayonet cap 60 of the lighting device 100 is attached to a socket provided at the ceiling of a room or a lighting fixture, when electrical power is supplied from an indoor power supply or the like to the socket, a constant current is supplied to the light source 40 via the power supply circuit (not shown) housed in the bayonet cap 60, the cap connector 23, or the columnar support 21, or an external power supply. With this, the light source 40 emits light.

[0035] Referring now to Fig. 2, the functions of the lens 30 are described. The principal component of light emitted from the light source 40 is totally reflected by the upper surface (concave surface) of the total reflection portion 30b, and is temporarily released from the cylindrical side surface of the total reflection portion 30b. The principal component of the light further enters the diffusion portion 30a, and is diffused and transmitted by this diffusion portion 30a. Accordingly, the light is released in the transverse direction and obliquely upward directions in Fig. 2, rather than in a backward

direction or in the emission direction of the light source 40.

[0036] The light that is not totally reflected by the upper surface or the concave surface of the reflection portion 30b passes through the upper surface of the reflection portion 30b. The light further enters the diffusion portion 30a, and is diffused and transmitted by this diffusion portion 30a. Accordingly, the light is released in a forward direction or the emission direction of the light source 40.

[0037] In the above manner, light emitted from the light source 40 is eventually turned into a wide light distribution by the diffusion portion 30a, and is diffused and transmitted as a uniform light distribution.

[0038] Also, since the outer surface of the diffusion portion 30a is similar in shape to the inner surface of the globe 10, this outer surface is substantially at the same distance from the globe 10 at any portion. With this, the light distribution characteristics of light released from the surface of the diffusion portion 30a are reflected by the globe 10. That is, as long as the light distribution is uniform, the globe 10 appears to be uniformly emitting light.

[0039] The largest diameters of the diffusion portion 30a and the total reflection portion 30b are equal to or smaller than the diameter of the opening portion of the globe 10. Accordingly, the lenses 30a and 30b can be inserted into the globe 10. In a case where the largest diameters of the lenses 30a and 30b are equal to or greater than the diameter of the opening portion of the globe 10, on the other hand, it is necessary to perform a process of dividing the globe 10, for example. By doing so, the processing load can be effectively reduced.

[0040] While emitting light, the light source 40 generates heat. This heat is transferred from the light source 40 to the substrate 41. The heat then propagates in the substrate 41, and reaches the base 20. After reaching the base 20, the heat is transferred to the columnar support 21 through the inside of the base 20. Part of the heat transferred to the columnar support 21 is transferred to the globe 10 by convection and heat radiation from the surface of the columnar support 21, and the remaining part of the heat is transferred to the globe connector 22 by heat conduction. Part of the heat transferred to the globe connector 22 is transferred to the globe 10, and the remaining part of the heat is transferred to the cap connector 23. The heat transferred to the cap connector 23 is then transferred to the bayonet cap 60 via the cap connector 23. In this case, the substrate 41 and the base 20, the base 20 and the columnar support 21, the columnar support 21 and the globe connector 22, the globe connector 22 and the globe 10, the globe connector 22 and the cap connector 23, and the cap connector 23 and the bayonet cap 60 are thermally connected with a grease, a sheet, a tape, or the like, which excels in heat conductivity, or by screwing with a screw or the like, as described above.

[0041] So as to facilitate heat release by radiation from the columnar support 21 to the globe 10, the radiation layer 80 is provided on the surface of the columnar support 21. The radiation layer 80 is formed from alumite or a coating formed through a surface treatment. If a material having a low absorptivity with respect to visible light, such as a white-color coating, is used as the radiation layer 80, light loss on the surface of the columnar support can be reduced.

[0042] As the radiation layer 80 releases heat from the columnar support 21 to the globe 10 in a noncontact manner as described above, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100 can be increased. Also, the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100 becomes higher.

[0043] In a case where mirror finishing is performed through polishing or metal vapor deposition, heat release by radiation is not facilitated, but light loss on the surface of the columnar support can be reduced as in the case with a white-color coating.

[0044] A protruding portion or a groove for increasing the area of contact with the globe 10 is formed at an end of the globe connector 22. The globe connector 22 and the globe 10 are secured to each other with an adhesive agent having excellent heat-resisting properties.

[0045] So as to facilitate heat release from the globe connector 22 to the surroundings, a radiation layer may be provided on the surface of the globe connector 22 in contact with air. The radiation layer is formed from alumite or a coating formed through a surface treatment. If a material having a low absorptivity with respect to visible light, such as a white-color coating, is used as the radiation layer, light loss on the globe connector surface can be reduced.

[0046] Where the surfaces of the columnar support 21 and the globe 10 are flat, A_i represents the surface area of the columnar support 21, l_g represents the length of the columnar support 21, r_i represents the radius of the columnar support 21 approximated by a sphere having an equivalent surface area, and r_{imin} represents r_i at a time when the junction of the light source 40 has a heat-resistant temperature, the surface area A_i satisfies the following expression (1):

$$4\pi r_{imin}^2 \leq A_i \quad (1)$$

[0047] Where $R_{bulb}(r_i)$ represents the heat resistance of the entire lighting device 100, Q_i represents the heating value of the light source 40, and ΔT_{jmax} represents the increase in the heat-resistant temperature of the junction of the light source 40, r_{imin} satisfies the following expression (2):

$$\Delta T_{jmax} = R_{bulb}(r_{imin})Q_l \quad (2)$$

[0048] Where R_{lc} represents the resistance to heat from the junction of the light source 40 to the surroundings via the bayonet cap 60, R_{gc} represents the resistance to heat from the surface of the globe connector 22 in contact with external air to the surroundings, R_{lp} represents the resistance to heat from the junction of the light source 40 to the surface of the columnar support 21, R_{ga} represents the resistance to heat from the surface of the globe 10 to the surroundings, and $R_a(r_i)$ represents the resistance to heat generated by the convection between the columnar support 21 and the globe 10 and radiation, $R_{bulb}(r_{imin})$ including r_i satisfies the following expression (3):

$$R_{bulb}(r_i) = \frac{R_{lc} R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}}{R_{lc} R_{gc} + R_{lc} \{R_{lp} + R_a(r_i) + R_{ga}\} + R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}} \quad (3)$$

[0049] Where $R_c(r_i)$ represents the resistance to heat generated by the convection between the columnar support 21 and the globe 10, and $R_r(r_i)$ represents the resistance to heat generated by radiation between the columnar support 21 and the globe 10, $R_a(r_i)$ including r_i satisfies the following expression (4):

$$R_a(r_i) = \frac{R_c(r_i) R_r(r_i)}{R_c(r_i) + R_r(r_i)} \quad (4)$$

[0050] Where T_i represents the mean temperature of the surface of the columnar support 21, T_o represents the mean temperature of the inner surface of the globe, and r_o represents the equivalent radius of the globe 10 approximated by a sphere, $R_c(r_i)$ including r_i satisfies the following expression (5):

$$R_c(r_i) = 1.7 \times 10^{-7} \frac{1}{(T_i - T_o)} \left(\frac{1}{r_i} - \frac{1}{r_o} \right) (r_i^{-7/5} + r_o^{-7/5})^5 \quad (5)$$

[0051] Where ε_i represents the mean emissivity of the surface of the columnar support 21, and ε_o represents the mean emissivity of the inner surface of the globe, $R_r(r_i)$ including r_i satisfies the following expression (6):

$$R_r(r_i) = \frac{\left\{ \frac{1}{\varepsilon_i} + \frac{r_i^2}{r_o^2} \left(\frac{1}{\varepsilon_o} - 1 \right) \right\}}{4\pi r_i^2 \sigma (T_i + T_o) (T_i^2 + T_o^2)} \quad (6)$$

[0052] Meanwhile, so as to facilitate heat release to the globe 10 by the convection from the columnar support 21, an appropriate distance needs to be maintained between the columnar support 21 and the globe 10, as shown in Fig. 3. Where d_n represents the mean distance obtained by integrating the distance from the surface of the columnar support 21 to the inner surface of the globe 10 with respect to the central axis from the upper end to the lower end of the columnar support in a plane perpendicular to the central axis 201 of the lighting device 100, l_g represents the length of the columnar support 21, β represents the coefficient of volume expansion, T_i represents the temperature of the surface of the columnar support 21, T_g represents the mean temperature of the inner surface of the globe 10 facing the columnar support 21, and ν represents the dynamic coefficient of viscosity, d_n is expressed by the following equation (7):

$$d_n = \left(\frac{1400}{Gr_i} \right)^{\frac{1}{3.389}} l_g \quad (7)$$

[0053] The Grashof number Gr_l in the above equation is expressed by the following equation (8):

$$Gr_l = \frac{g\beta(T_i - T_g)l_g^3}{\nu^2} \quad (8)$$

[0054] When the distance between the columnar support 21 and the globe 10 is equal to or longer than d_n expressed by the equation (7), heat transfer by gas becomes dominant, and the heat transfer can be facilitated while the distance between the globe 10 and the columnar support 21 is maintained. Accordingly, the transparency of the lighting device 100 becomes higher.

[0055] The relationship with the surface area A_i of the columnar support 21 is represented by the following expression (9):

$$A_i \leq 2\pi d_n l_g \quad (9)$$

[0056] In the example structure described in this embodiment, the globe 10 covers substantially the entire surface of the lighting device 100, except for the bayonet cap 60. However, the globe 10 may be employed in conjunction with a metal housing, and be designed to cover only part of the surface of the lighting device 100. In this case, heat is released not only from the surface of the globe 10 but also directly from the surface of the metal housing not shown in the drawing.

[0057] Heat released from the columnar support 21 warms the air inside the globe, and the warmed air moves upward along the surface of the columnar support 21 in the opposite direction from gravity by virtue of natural convection, as indicated by the flow lines 71 in Fig. 4. The air that has reached the upper end of the columnar support 21 is gradually cooled by the inner surface of the globe 10, and then moves downward in the direction of gravity. By virtue of this airflow, heat transfer from the columnar support 21 to the globe 10 is facilitated, and the lighting device 100 is further cooled. When the air flows upward along the circumference of the columnar support 21, the temperature of the flowing air gradually increases. That is, in the vicinities of the surface of the columnar support 21, the temperature of the air near the lower end of the columnar support 21 is the lowest, and the temperature of the air is higher in a portion closer to the upper end. As the light source 40 is provided at the lower end of the columnar support 21 as in this embodiment, the light source 40 can be efficiently cooled by air at a lower temperature. As the columnar support 21 releases heat to the globe 10 in a noncontact manner by virtue of convection, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100 can be increased. Also, the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100 becomes higher.

[0058] Referring now to Fig. 5, the conditions for obtaining a wider light distribution are described. Light emitted from the light source 40 is released to the surroundings of the lighting device 100 via the lens (light guide member) 30. Here, the origin of the distribution angle of light from the lens 30 is represented by O. Also, $1/2$ of the distribution angle of light emitted from the origin O of the lens 30 is represented by an angle θ_d . In the plane perpendicular to the central axis 201 of the lighting device extending vertically downward through the origin O of the lens 30, the distance from the central axis 201 to an end portion of each of the optically-opaque components including the cap connector 23, the globe connector 22, the columnar support 21, the base 20, the lens connector 50, and the bayonet cap 60 is represented by r_m , the distance from the plane that extends through the origin O of the lens 30 and is perpendicular to the central axis 201 is represented by l_m , and the shortest distance from the central axis 201 to the surface of the light source 40 facing the lens 30 is represented by r_l . In that case, the distance r_m is preferably within the range shown in the following expression (10):

$$r_l \leq r_m \leq l_m |\tan \theta_d| \quad (10)$$

[0059] It should be noted that the distance r_l to the surface of the light source 40 facing the lens 30 means the shortest distance from the origin of the surface, which is the point of intersection between the central axis and the surface, to the outer periphery of the surface. The distance from the plane that extends through the origin O of the lens 30 and is perpendicular to the central axis 201 to an end portion means the shortest distance from the end portion to each point on the plane. Although the origin O of the light distribution angle is located near the center of the lens on the central axis in Fig. 5, the origin O may be located in any site of the lens. It should be noted that θ_d may be arbitrarily set, such as within $1/2$ of the light intensity at lower portions, depending on the required light distribution angle. Although the axis of symmetry of the light distribution is the same as the central axis of the lighting device, the axis of symmetry of the light

distribution may run through any point on the light-emitting surface of the LED light source.

[0060] With this structure, the lighting device 100 can obtain the light distribution angle corresponding to the lens 30, and luminous efficiency also becomes higher. In Fig. 5, the distance r_m and the distance l_m are measured from an end portion of the lens connector 50.

[0061] A lighting device according to a modification of the first embodiment shown in Fig. 6 differs from the lighting device shown in Fig. 1(b) in that the columnar support 21 may not be curved. As shown in Fig. 6, the columnar support 21 may have a surface oblique to the central axis, or may have a surface parallel to the central axis. As the columnar support 21 is not curved, the volume of the hollow in the columnar support 21 becomes larger, and the manufacturability of the columnar support 21 becomes higher.

[0062] Where the cylindrical shape of the columnar support 21 is curved along the inner surface of the globe 10 to widen the space between the columnar support 21 and the globe 10 as in this embodiment, convection is accelerated, or the fluid resistance is reduced, so that heat release from the columnar support 21 to the globe 10 can be facilitated.

[0063] In this embodiment, the perimeter of the columnar support 21 in a cross-section perpendicular to the central axis is made to become smaller as it becomes further away from the base 20. With this, the surface area of the columnar support 21 and the cross-sectional area perpendicular to the central axis can be reduced as the heat quantity becomes gradually smaller due to heat release from the surface of the columnar support 21. Accordingly, weight can be reduced, and the transparency of the lighting device 100 can be increased.

[0064] In this embodiment, a hollow is formed inside the columnar support 21, an opening portion is formed only at one end on the side of the bayonet cap 60 or at both ends including the end portion on the side of the light source 41, and an opening portion is further formed in the side surface of the cylindrical portion of the columnar support 21. With this structure, the wiring line 90 electrically connected to the LED 40 can be housed even in the bayonet cap 60. Accordingly, the external appearance is improved, and at the same time, the possibility that slack of the wiring line accidentally blocks light can be lowered.

[0065] The lens connector 50 is screwed to the base 20 with a screw or the like, and secures the lens 30 with an adhesive agent or the like. As shown in Fig. 1(b), a space is left between the lens 30 and the light source 40. As a space is left between the lens 30 and the light source 40, the difference in the coefficient of thermal expansion between the light source 40 and the lens 30 does not have any influence. Also, the lens 30 can be located at a distance from the light source 40 that is to have a high temperature, or the temperature of the lens 30 can be made equal to or lower than the temperature of the light source 40. With this structure, in a case where a material that has a heat-resistant temperature equal to or lower than that of the light source 40, such as acrylic, is used as the material of the lens 30, higher electrical power can be supplied to the light source 40, and a higher total flux can be obtained.

[0066] The wiring line 90 may be connected directly to the bayonet cap, or one end of the wiring line 90 may be connected to the base 20. As the wiring line 90 is connected to the base 20, the amount of wiring can be reduced, and the external appearance can be improved. In this case, the base 20, the globe connector 22, and the cap connector 23 need to be conductive components, for example, so that the columnar support 21 and the substrate 41 are electrically connected.

[0067] Although the base 20, the columnar support 21, the globe connector 22, and the cap connector 23 are separate components in this embodiment, some or all of these components may be integrally formed as one component. In this case, it is difficult to manufacture the components. However, the contact heat resistance between the joining portions of the components can be eliminated, and radiation performance can be further improved.

[0068] In this embodiment, the cap connector 60 has electrical conductivity. However, the cap connector may be made of a material having excellent electrical insulating properties (such as PBT (polybutylene terephthalate), polycarbonate, or PEEK (polyetheretherketone)), or a layer having excellent electrical insulating properties may be formed on the surface of the cap connector. In this case, electrical problems can be avoided when an electrical circuit (not shown) is provided in the cap connector 60. Both the positive terminal and the negative terminal of the wiring line 90 are connected to the electrical circuit. In a case where any electrical circuit is not provided, the wiring line 90 is connected directly to the bayonet cap.

[0069] In this embodiment, the power supply circuit is provided outside the lighting device 100. However, the power supply circuit may be housed in the bayonet cap 60, the cap connector 23, or the columnar support 21.

[0070] In the lighting device 100 of this embodiment, the columnar support 21 is provided inside the globe 10. Accordingly, heat can be efficiently released, and the radiation performance of the lighting device 100 can be improved.

[0071] As described above, according to this embodiment, radiation performance can be improved. Thus, a higher-output LED can be used, and the total flux can be increased accordingly. Also, the light distribution angle corresponding to the lens can be obtained. Thus, luminous efficiency can be increased.

(Second Embodiment)

[0072] Fig. 7 shows a lighting device according to a second embodiment. A lighting device 100A of the second em-

bodiment is the same as the lighting device 100 according to the modification of the first embodiment shown in Fig. 6, except that a light guide pillar 31 is used in place of the lens 30. In this specification, the lens 30 and the light guide pillar 31 are also called light guide members. The light guide pillar 31 is formed with a base portion 31a and a top end portion 31b, and these two portions are joined to form a hollow inside. In this hollow, a scatterer 32 is inserted, for example.

The scatterer 32 has a spherical structure in which particles of titanium oxide of approximately 1 to 10 μm in particle size, for example, are sealed with a transparent resin. Alternatively, the inner surface of the hollow may be roughened as the scatterer 32 by sandblasting, or may be coated. Light that enters the light guide pillar 31 from the light source 40 is scattered in the hollow and is then released to the outside. With the use of the light guide pillar 31, light can be released to the outside from a position at a distance from the light source 40, and the external appearance becomes more similar to that of an incandescent bulb. The light guide pillar 31 may be formed only with the base portion 31a, without the top end portion 31b.

[0073] If the center point O of the light distribution of the light guide pillar is set at the center of the globe 10, for example, light from the light source 40 is released from the center point O or the center of the globe. The largest diameter of the light guide pillar 31 is equal to or smaller than the diameter of the opening portion of the globe 10. Accordingly, the light guide pillar 31 can be inserted into the globe 10. The material of the light guide pillar 31 is preferably acrylic, polycarbonate, cycloolefin polymer, glass, or the like, which has high optical transparency.

[0074] In the second embodiment, radiation performance can be improved as in the first embodiment. Thus, a higher-output LED can be used, and the total flux can be increased accordingly.

[0075] Also, in the lighting device 100A of the second embodiment, the light distribution angle corresponding to the light guide pillar 31 can be obtained, and luminous efficiency can be increased.

(Third Embodiment)

[0076] Fig. 8 shows a lighting device according to a third embodiment. A lighting device 100B of the third embodiment is the same as the lighting device 100A of the second embodiment shown in Fig. 7, except that a cover 24 is further used on the side surface of the light guide pillar 31 so as to cover part of the base portion 31a. The cover 24 may or may not have a radiation layer 81 provided on the surface thereof. With the use of the cover 24, light direct from the light source 40 can be prevented from being released to the outside. With the use of the cover 24, a heat releasing area can be secured even in a case where the light guide pillar 31 is extended. Accordingly, the radiation performance of the lighting device 100A can be improved.

[0077] The cover 24 may be formed integrally with at least one of the columnar support 21, the base 20, and a substrate connector 50. The material of the cover 24 is a material with excellent heat conductivity, such as an aluminum alloy or a copper alloy. So as to reduce absorption of light emitted from the light source 40, the inner surface of the cover 24 may be subjected to mirror finishing, such as coating, polishing, or metal vapor deposition. If a material having a low absorptivity with respect to visible light, such as a white-color coating, is used, light loss on the inner surface of the cover 24 can be reduced.

[0078] In the third embodiment, radiation performance can be improved as in the first embodiment. Thus, a higher-output LED can be used, and the total flux can be increased accordingly. Also, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100B can be increased, and the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100B becomes higher.

[0079] In the third embodiment, the cover 24 is housed within $1/2$ of the light distribution angle θ_d of the light guide pillar 31, so that the lighting device 100A can obtain the light distribution angle corresponding to the light guide pillar 31. Accordingly, luminous efficiency can be increased. The cover 24 may be used in conjunction with the lens 30 as a light guide member.

(Fourth Embodiment)

[0080] Fig. 9 shows a lighting device according to a fourth embodiment. A lighting device 100C of the fourth embodiment is the same as the lighting device 100B of the third embodiment shown in Fig. 8, except that vent holes 91 connecting the outer surface and the inner surface are further formed in each of the columnar support 21 and the cover 24. The vent holes 91 are preferably formed in the direction of gravity in line with the opening portion of the cover 24 so that air flows inside the columnar support 21 and the cover 24 as indicated by flow lines 71. So as to cause air to flow smoothly in the columnar support 21 and the cover 24, vent holes may also be formed in the base 20 or the lens connector 50. As the vent holes are formed, heat can be released not only from the surfaces but also from the inner surfaces of the columnar support 21 and the cover 24, and higher radiation performance than that of the lighting device 100B of the third embodiment can be achieved. With this, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100C can be increased, and the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100C becomes higher.

[0081] In the fourth embodiment, radiation performance can be further improved. Thus, a higher-output LED can be used, and the total flux can be increased accordingly.

[0082] Also, in the fourth embodiment, the light distribution angle corresponding to the light guide pillar 31 can be obtained, and luminous efficiency can be increased as in the third embodiment.

(Fifth Embodiment)

[0083] Fig. 10(a) shows a lighting device according to a fifth embodiment. A lighting device 100D of the fifth embodiment is the same as the lighting device 100B of the third embodiment shown in Fig. 8, except that protruding fins are further formed on the columnar support 21 and the cover 24. Fig. 10(b) shows a cross-section of the fins taken along the section line B-B. As the protruding fins are formed on the outer surfaces of the columnar support 21 and the cover 24 as shown in Fig. 10(b), the heat releasing area can be increased, and higher radiation performance than that of the lighting device 100B of the third embodiment can be achieved. With this, the proportion of the surface of the globe 10 to the outer surface of the lighting device 100D can be increased, and the surface areas of the opaque members provided inside the globe 10 can be reduced. Accordingly, the transparency of the lighting device 100D becomes higher.

[0084] In the fifth embodiment, radiation performance can be further improved. Thus, a higher-output LED can be used, and the total flux can be increased accordingly.

[0085] Also, in the fifth embodiment, the light distribution angle corresponding to the light guide pillar 31 can be obtained, and luminous efficiency can be increased as in the third embodiment.

[0086] 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 methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems 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 lighting device comprising:

- a globe having an opening at one end and a hollow inside;
- a base housed in the globe;
- a light source including at least one LED disposed on the base, the light source being housed in the globe;
- a light guide member configured to cover a light-emitting surface of the light source, the light guide member having optical transparency, the light guide member being housed in the globe;
- a columnar support configured to support the base, the columnar support being housed in the globe and being located on the opposite side from the light source and the light guide member;
- a radiation layer configured to radiate heat, the radiation layer being disposed on a surface of the columnar support;
- a globe connector connected to the columnar support at the one end of the globe;
- a cap connector connected to the globe connector;
- a bayonet cap configured to supply electrical power to the light source, the bayonet cap being connected to the cap connector; and
- a wiring line configured to electrically connect the bayonet cap and the light source.

2. The device according to claim 1, further comprising a cover configured to surround the light guide member.

3. The device according to claim 1, wherein
the light guide member is a lens, and
the largest diameter of the lens is smaller than a diameter of the opening at the one end of the globe.

4. The device according to claim 1, wherein
the light guide member is a lens, and
an outer surface of the lens has a shape similar to an inner surface of the globe.

5. The device according to claim 1, wherein
the light guide member is a light guide pillar having one of a hollow therein and a concave portion at a top end

portion, and

a scatterer is disposed in the one of the hollow and the concave portion of the light guide pillar, or a surface having the one of the hollow and the concave portion formed therein is subjected to coating or blast finishing.

6. The device according to claim 1, wherein a perimeter of the columnar support in a cross-section perpendicular to a central axis of the columnar support varies in a direction toward the bayonet cap.
7. The device according to claim 2, wherein a perimeter of the cover in a cross-section perpendicular to a central axis of the cover varies in a direction toward the bayonet cap.
8. The device according to claim 1, wherein the columnar support has a surface parallel or oblique to a central axis of the lighting device.
9. The device according to claim 2, wherein the cover has a surface parallel or oblique to a central axis of the lighting device.
10. The device according to claim 1, wherein a hollow is formed in the columnar support.
11. The device according to claim 1, wherein the columnar support has at least one hole for allowing the wiring line to extend therethrough.
12. The device according to claim 2, wherein the cover has at least one hole for allowing the wiring line to extend therethrough.
13. The device according to claim 1, wherein the columnar support has a vent hole connecting an outer surface and an inner surface.
14. The device according to claim 2, wherein the cover has a vent hole connecting an outer surface and an inner surface.
15. The device according to claim 1, wherein the columnar support has protruding fins on an outer surface.
16. The device according to claim 2, wherein the cover has protruding fins on an outer surface.
17. The device according to claim 1, wherein where A_i represents a total surface area of the columnar support, l_g represents a total length of the columnar support, r_i represents a radius of the columnar support having the total surface area approximated by an equivalent sphere, r_{imin} represents the r_i at a time when a junction of the light source is at a heat-resistant temperature, and d_n represents a mean distance obtained by integrating distances from a surface of the columnar support to an inner surface of the globe with respect to a central axis of the columnar support from an upper end to a lower end of the columnar support in a plane perpendicular to the columnar support, the following expression (1) is satisfied,

$$4\pi r_{imin}^2 \leq A_i \leq 2\pi d_n l_g \quad (1)$$

where $R_{bulb}(r_i)$ represents a heat resistance of the entire lighting device, Q_i represents a heating value of the light source, and ΔT_{jmax} represents increase in the heat-resistant temperature of the junction of the light source, the following expression (2) is satisfied,

$$\Delta T_{jmax} = R_{bulb}(r_{imin})Q_i \quad (2)$$

where R_{lc} represents a resistance to heat from the junction of the light source to surroundings via the bayonet cap, R_{gc} represents a resistance to heat from a surface of the globe connector in contact with external air to the surroundings, R_{lp} represents a resistance to heat from the junction of the light source to the surface of the columnar support, R_{ga} represents a resistance to heat from a surface of the globe to the surroundings, and $R_a(r_i)$ represents a resistance to heat generated by convection and radiation between the columnar support and the globe, the following expression (3) is satisfied,

$$R_{bulb}(r_i) = \frac{R_{lc} R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}}{R_{lc} R_{gc} + R_{lc} \{R_{lp} + R_a(r_i) + R_{ga}\} + R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}} \quad (3)$$

where $R_c(r_i)$ represents a resistance to heat generated by convection between the columnar support and the globe, and $R_r(r_i)$ represents a resistance to heat generated by radiation between the columnar support and the globe, the following expression (4) is satisfied,

$$R_a(r_i) = \frac{R_c(r_i) R_r(r_i)}{R_c(r_i) + R_r(r_i)} \quad (4)$$

where T_i represents a mean temperature of the surface of the columnar support, T_o represents a mean temperature of the inner surface of the globe, and r_o represents an equivalent radius of the globe approximated by a sphere, the following expression (5) is satisfied,

$$R_c(r_i) = 1.7 \times 10^{-7} \frac{1}{(T_i - T_o)} \left(\frac{1}{r_i} - \frac{1}{r_o} \right) (r_i^{-7/5} + r_o^{-7/5})^5 \quad (5)$$

where ε_i represents a mean emissivity of the surface of the columnar support, and ε_o represents a mean emissivity of the inner surface of the globe, the following expression (6) is satisfied,

$$R_r(r_i) = \frac{\left\{ \frac{1}{\varepsilon_i} + \frac{r_i^2}{r_o^2} \left(\frac{1}{\varepsilon_o} - 1 \right) \right\}}{4\pi r_i^2 \sigma (T_i + T_o)(T_i^2 + T_o^2)} \quad (6)$$

where β represents a coefficient of volume expansion of air, T_g represents a mean temperature of the inner surface of the globe facing the surface of the columnar support, ν represents a dynamic coefficient of viscosity, g represents gravity, and Gr_i represents a Grashof number, the following expressions (7) and (8) are satisfied,

$$d_n = \left(\frac{1400}{Gr_i} \right)^{\frac{1}{3.389}} l_g \quad (7)$$

$$Gr_i = \frac{g\beta(T_i - T_g) l_g^3}{\nu^2} \quad (8)$$

18. The device according to claim 2, wherein

where A_i represents a sum of surface areas of the columnar support and the cover, l_g represents a sum of lengths of the columnar support and the cover, r_i represents a radius at a time when the sum of the surface areas of the columnar support and the cover is approximated by an equivalent sphere, r_{imin} represents the r_i at a time when a junction of the light source is at a heat-resistant temperature, and d_n represents a mean distance obtained by integrating distances from surfaces of the columnar support and the cover to an inner surface of the globe with respect to a central axis of the cover from an upper end to a lower end of the columnar support and the cover in a plane perpendicular to the columnar support, the following expression (1) is satisfied,

$$4\pi r_{imin}^2 \leq A_i \leq 2\pi d_n l_g \quad (1)$$

where $R_{bulb}(r_i)$ represents a heat resistance of the entire lighting device, Q_l represents a heating value of the light source, and ΔT_{jmax} represents increase in the heat-resistant temperature of the junction of the light source, the following expression (2) is satisfied,

$$\Delta T_{jmax} = R_{bulb}(r_{imin})Q_l \quad (2)$$

where R_{lc} represents a resistance to heat from the junction of the light source to surroundings via the bayonet cap, R_{gc} represents a resistance to heat from a surface of the globe connector in contact with external air to the surroundings, R_{lp} represents a resistance to heat from the junction of the light source to the surfaces of the columnar support and the cover, R_{ga} represents a resistance to heat from a surface of the globe to the surroundings, and $R_a(r_i)$ represents a resistance to heat generated by convection and radiation between the columnar support and the cover, and the globe, the following expression (3) is satisfied,

$$R_{bulb}(r_i) = \frac{R_{lc} R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}}{R_{lc} R_{gc} + R_{lc} \{R_{lp} + R_a(r_i) + R_{ga}\} + R_{gc} \{R_{lp} + R_a(r_i) + R_{ga}\}} \quad (3)$$

where $R_c(r_i)$ represents a resistance to heat generated by convection between the columnar support and the cover, and the globe, and $R_r(r_i)$ represents a resistance to heat generated by radiation between the columnar support and the cover, and the globe, the following expression (4) is satisfied,

$$R_a(r_i) = \frac{R_c(r_i)R_r(r_i)}{R_c(r_i) + R_r(r_i)} \quad (4)$$

where T_i represents a mean temperature of the surfaces of the columnar support and the cover, T_o represents a mean temperature of the inner surface of the globe, and r_o represents an equivalent radius of the globe approximated by a sphere, the following expression (5) is satisfied,

$$R_c(r_i) = 1.7 \times 10^{-7} \frac{1}{(T_i - T_o)} \left(\frac{1}{r_i} - \frac{1}{r_o} \right) (r_i^{-7/5} + r_o^{-7/5})^\beta \quad (5)$$

where ε_i represents a mean emissivity of the surfaces of the columnar support and the cover, and ε_o represents a mean emissivity of the inner surface of the globe, the following expression (6) is satisfied,

$$R_r(r_i) = \frac{\left\{ \frac{1}{\varepsilon_i} + \frac{r_i^2}{r_o^2} \left(\frac{1}{\varepsilon_o} - 1 \right) \right\}}{4\pi r_i^2 \sigma (T_i + T_o) (T_i^2 + T_o^2)} \quad (6)$$

where β represents a coefficient of volume expansion of air, T_g represents a mean temperature of the inner surface of the globe facing the columnar support and the cover, ν represents a dynamic coefficient of viscosity, g represents gravity, and Gr_l represents a Grashof number, the following expressions (7) and (8) are satisfied,

$$d_n = \left(\frac{1400}{Gr_i} \right)^{\frac{1}{3.389}} l_g \quad (7)$$

$$Gr_i = \frac{g\beta(T_i - T_g) l_g^3}{\nu^2} \quad (8)$$

19. The device according to claim 17, wherein the surface area A_i of the columnar support is expressed as

$$A_i = 4\pi r_{imin}^2.$$

20. The device according to claim 18, wherein a sum A_i of the surface area of the columnar support and the surface area of the cover is expressed as

$$A_i = 4\pi r_{imin}^2.$$

21. The device according to claim 1, wherein,

where an angle θ_d represents 1/2 of a distribution angle of light released from the light guide member, r_m represents a distance from a central axis of the light distribution to an end portion of each of optically-opaque components among the cap connector, the globe connector, the columnar support, the base, and the bayonet cap in a plane perpendicular to the central axis of the light distribution, l_m represents a distance from a plane perpendicular to the central axis through the center of the light guide member to the end portion, and r_l represents the shortest distance from the central axis to a surface of the light source facing the light guide member, the distance r_m is within the range expressed as follows:

$$r_l \leq r_m \leq l_m |\tan \theta_d|.$$

22. The device according to claim 2, wherein,

where an angle θ_d represents 1/2 of a distribution angle of light released from the light guide member, r_m represents a distance from a central axis of the light distribution to an end portion of each of optically-opaque components among the cap connector, the globe connector, the columnar support, the base, the bayonet cap, and the cover in a plane perpendicular to the central axis of the light distribution, l_m represents a distance from a plane perpendicular to the central axis through the center of the light guide member to the end portion, and r_l represents the shortest distance from the central axis to a surface of the light source facing the light guide member, the distance r_m is within the range expressed as follows:

$$r_l \leq r_m \leq l_m |\tan \theta_d|.$$

23. The device according to claim 1, wherein the cap connector is made of ceramic or a metal, and has an opening portion in a surface connected to the columnar support.

24. The device according to claim 1, wherein

the base, the columnar support, the globe connector, and the cap connector have conductive properties, and the cap connector is electrically connected to the light source.

25. A lighting device comprising:

a globe having an opening at one end and a hollow inside;
a base housed in the globe;

a light source including at least one LED disposed on the base, the light source being housed in the globe;
a light guide member configured to cover a light-emitting surface of the light source, the light guide member having optical transparency, the light guide member being housed in the globe;
a columnar support configured to support the base, the columnar support being housed in the globe and being located on the opposite side from the light source and the light guide member;
a globe connector connected to the columnar support at the one end of the globe;
a cap connector connected to the globe connector;
a bayonet cap configured to supply electrical power to the light source, the bayonet cap being connected to the cap connector; and
a wiring line configured to electrically connect the bayonet cap and the light source.

26. The device according to claim 25, further comprising
a cover configured to surround the light guide member.

27. The device according to claim 25, wherein
the light guide member is a lens, and
the largest diameter of the lens is smaller than a diameter of the opening at the one end of the globe.

28. The device according to claim 25, wherein
the light guide member is a lens, and
an outer surface of the lens has a shape similar to an inner surface of the globe.

29. The device according to claim 25, wherein
the light guide member is a light guide pillar having one of a hollow therein and a concave portion at a top end portion, and
a scatterer is disposed in the one of the hollow and the concave portion of the light guide pillar, or a surface having the one of the hollow and the concave portion formed therein is subjected to coating or blast finishing.

30. The device according to claim 25, wherein a perimeter of the columnar support in a cross-section perpendicular to a central axis of the columnar support varies in a direction toward the bayonet cap.

31. The device according to claim 26 wherein a perimeter of the cover in a cross-section perpendicular to a central axis of the cover varies in a direction toward the bayonet cap.

32. The device according to claim 25, wherein the columnar support has a surface parallel or oblique to a central axis of the lighting device.

33. The device according to claim 26, wherein the cover has a surface parallel or oblique to a central axis of the lighting device.

34. The device according to claim 25, wherein a hollow is formed in the columnar support.

35. The device according to claim 25, wherein the columnar support has at least one hole for allowing the wiring line to extend therethrough.

36. The device according to claim 26, wherein the cover has at least one hole for allowing the wiring line to extend therethrough.

37. The device according to claim 25, wherein the columnar support has a vent hole connecting an outer surface and an inner surface.

38. The device according to claim 26, wherein the cover has a vent hole connecting an outer surface and an inner surface.

39. The device according to claim 25, wherein the columnar support has protruding fins on an outer surface.

40. The device according to claim 26, wherein the cover has protruding fins on an outer surface.

41. The device according to claim 25, wherein where A_i represents a total surface area of the columnar support, I_g

represents a total length of the columnar support, r_i represents a radius of the columnar support having the total surface area approximated by an equivalent sphere, r_{imin} represents the r_i at a time when a junction of the light source is at a heat-resistant temperature, and d_n represents a mean distance obtained by integrating distances from a surface of the columnar support to an inner surface of the globe with respect to a central axis of the columnar support from an upper end to a lower end of the columnar support in a plane perpendicular to the columnar support, the following expression (1) is satisfied,

$$4\pi r_{imin}^2 \leq A_i \leq 2\pi d_n l_g \quad (1)$$

where $R_{bulb}(r_i)$ represents a heat resistance of the entire lighting device, Q_i represents a heating value of the light source, and ΔT_{jmax} represents increase in the heat-resistant temperature of the junction of the light source, the following expression (2) is satisfied,

$$\Delta T_{jmax} = R_{bulb}(r_{imin})Q_i \quad (2)$$

where R_{lc} represents a resistance to heat from the junction of the light source to surroundings via the bayonet cap, R_{gc} represents a resistance to heat from a surface of the globe connector in contact with external air to the surroundings, R_{lp} represents a resistance to heat from the junction of the light source to the surface of the columnar support, R_{ga} represents a resistance to heat from a surface of the globe to the surroundings, and $R_a(r_i)$ represents a resistance to heat generated by convection and radiation between the columnar support and the globe, the following expression (3) is satisfied,

$$R_{bulb}(r_i) = \frac{R_{lc}R_{gc}\{R_{lp} + R_a(r_i) + R_{ga}\}}{R_{lc}R_{gc} + R_{lc}\{R_{lp} + R_a(r_i) + R_{ga}\} + R_{gc}\{R_{lp} + R_a(r_i) + R_{ga}\}} \quad (3)$$

where $R_c(r_i)$ represents a resistance to heat generated by convection between the columnar support and the globe, and $R_r(r_i)$ represents a resistance to heat generated by radiation between the columnar support and the globe, the following expression (4) is satisfied,

$$R_a(r_i) = \frac{R_c(r_i)R_r(r_i)}{R_c(r_i) + R_r(r_i)} \quad (4)$$

where T_i represents a mean temperature of the surface of the columnar support, T_o represents a mean temperature of the inner surface of the globe, and r_o represents an equivalent radius of the globe approximated by a sphere, the following expression (5) is satisfied,

$$R_c(r_i) = 1.7 \times 10^{-7} \frac{1}{(T_i - T_o)} \left(\frac{1}{r_i} - \frac{1}{r_o} \right) (r_i^{-7/5} + r_o^{-7/5})^5 \quad (5)$$

where ε_i represents a mean emissivity of the surface of the columnar support, and ε_o represents a mean emissivity of the inner surface of the globe, the following expression (6) is satisfied,

$$R_r(r_i) = \frac{\left\{ \frac{1}{\varepsilon_i} + \frac{r_i^2}{r_o^2} \left(\frac{1}{\varepsilon_o} - 1 \right) \right\}}{4\pi r_i^2 \sigma (T_i + T_o) (T_i^2 + T_o^2)} \quad (6)$$

where β represents a coefficient of volume expansion of air, T_g represents a mean temperature of the inner surface of the globe facing the surface of the columnar support, ν represents a dynamic coefficient of viscosity, g represents gravity, and Gr_l represents a Grashof number, the following expressions (7) and (8) are satisfied,

$$d_n = \left(\frac{1400}{Gr_l} \right)^{\frac{1}{3.389}} l_g \quad (7)$$

$$Gr_l = \frac{g\beta(T_i - T_g)l_g^3}{\nu^2} \quad (8)$$

42. The device according to claim 26, wherein

where A_l represents a sum of surface areas of the columnar support and the cover, l_g represents a sum of lengths of the columnar support and the cover, r_l represents a radius at a time when the sum of the surface areas of the columnar support and the cover is approximated by an equivalent sphere, r_{imin} represents the r_l at a time when a junction of the light source is at a heat-resistant temperature, and d_n represents a mean distance obtained by integrating distances from surfaces of the columnar support and the cover to an inner surface of the globe with respect to a central axis of the cover from an upper end to a lower end of the columnar support and the cover in a plane perpendicular to the columnar support, the following expression (1) is satisfied,

$$4\pi r_{imin}^2 \leq A_l \leq 2\pi d_n l_g \quad (1)$$

where $R_{bulb}(r_l)$ represents a heat resistance of the entire lighting device, Q_l represents a heating value of the light source, and ΔT_{jmax} represents increase in the heat-resistant temperature of the junction of the light source, the following expression (2) is satisfied,

$$\Delta T_{jmax} = R_{bulb}(r_{imin})Q_l \quad (2)$$

where R_{lc} represents a resistance to heat from the junction of the light source to surroundings via the bayonet cap, R_{gc} represents a resistance to heat from a surface of the globe connector in contact with external air to the surroundings, R_{lp} represents a resistance to heat from the junction of the light source to the surfaces of the columnar support and the cover, R_{ga} represents a resistance to heat from a surface of the globe to the surroundings, and $R_a(r_l)$ represents a resistance to heat generated by convection and radiation between the columnar support and the cover, and the globe, the following expression (3) is satisfied,

$$R_{bulb}(r_l) = \frac{R_{lc} R_{gc} \{R_{lp} + R_a(r_l) + R_{ga}\}}{R_{lc} R_{gc} + R_{lc} \{R_{lp} + R_a(r_l) + R_{ga}\} + R_{gc} \{R_{lp} + R_a(r_l) + R_{ga}\}} \quad (3)$$

where $R_c(r_l)$ represents a resistance to heat generated by convection between the columnar support and the cover, and the globe, and $R_r(r_l)$ represents a resistance to heat generated by radiation between the columnar support and the cover, and the globe, the following expression (4) is satisfied,

$$R_a(r_l) = \frac{R_c(r_l)R_r(r_l)}{R_c(r_l) + R_r(r_l)} \quad (4)$$

where T_l represents a mean temperature of the surfaces of the columnar support and the cover, T_o represents a

mean temperature of the inner surface of the globe, and r_o represents an equivalent radius of the globe approximated by a sphere, the following expression (5) is satisfied,

$$R_c(r_i) = 1.7 \times 10^{-7} \frac{1}{(T_i - T_o)} \left(\frac{1}{r_i} - \frac{1}{r_o} \right) (r_i^{-7/5} + r_o^{-7/5})^5 \quad (5)$$

where ε_i represents a mean emissivity of the surfaces of the columnar support and the cover, and ε_o represents a mean emissivity of the inner surface of the globe, the following expression (6) is satisfied,

$$R_r(r_i) = \frac{\left\{ \frac{1}{\varepsilon_i} + \frac{r_i^2}{r_o^2} \left(\frac{1}{\varepsilon_o} - 1 \right) \right\}}{4\pi r_i^2 \sigma (T_i + T_o) (T_i^2 + T_o^2)} \quad (6)$$

where β represents a coefficient of volume expansion of air, T_g represents a mean temperature of the inner surface of the globe facing the columnar support and the cover, ν represents a dynamic coefficient of viscosity, g represents gravity, and Gr_l represents a Grashof number, the following expressions (7) and (8) are satisfied,

$$d_n = \left(\frac{1400}{Gr_l} \right)^{\frac{1}{3.389}} l_g \quad (7)$$

$$Gr_l = \frac{g\beta(T_i - T_g)l_g^3}{\nu^2} \quad (8)$$

43. The device according to claim 25, wherein the surface area A_i of the columnar support is expressed as

$$A_i = 4\pi r_{imin}^2.$$

44. The device according to claim 26, wherein a sum A_i of the surface area of the columnar support and the surface area of the cover is expressed as

$$A_i = 4\pi r_{imin}^2.$$

45. The device according to claim 25, wherein,

where an angle θ_d represents 1/2 of a distribution angle of light released from the light guide member, r_m represents a distance from a central axis of the light distribution to an end portion of each of optically-opaque components among the cap connector, the globe connector, the columnar support, the base, and the bayonet cap in a plane perpendicular to the central axis of the light distribution, l_m represents a distance from a plane perpendicular to the central axis through the center of the light guide member to the end portion, and r_l represents the shortest distance from the central axis to a surface of the light source facing the light guide member, the distance r_m is within the range expressed as follows:

$$r_l \leq r_m \leq l_m |\tan \theta_d|.$$

46. The device according to claim 26, wherein,

where an angle θ_d represents 1/2 of a distribution angle of light released from the light guide member, r_m represents a distance from a central axis of the light distribution to an end portion of each of optically-opaque components among the cap connector, the globe connector, the columnar support, the base, the bayonet cap, and the cover in a plane perpendicular to the central axis of the light distribution, l_m represents a distance from a plane perpendicular to the central axis through the center of the light guide member to the end portion, and r_l represents the shortest distance from the central axis to a surface of the light source facing the light guide member, the distance r_m is within the range expressed as follows:

$$r_l \leq r_m \leq l_m |\tan \theta_d|.$$

47. The device according to claim 25, wherein the cap connector is made of ceramic or a metal, and has an opening portion in a surface connected to the columnar support.

48. The device according to claim 25, wherein the base, the columnar support, the globe connector, and the cap connector have conductive properties, and the cap connector is electrically connected to the light source.

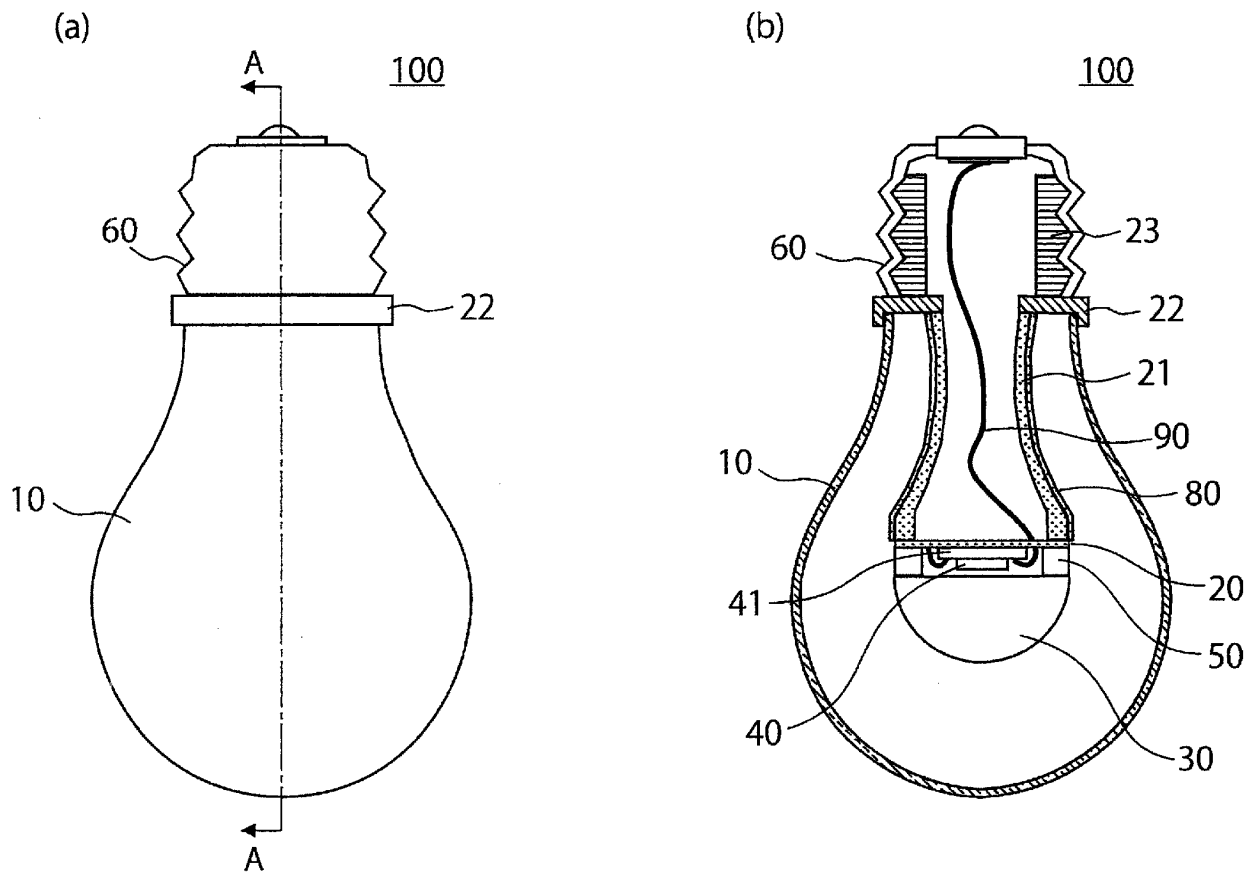


FIG. 1

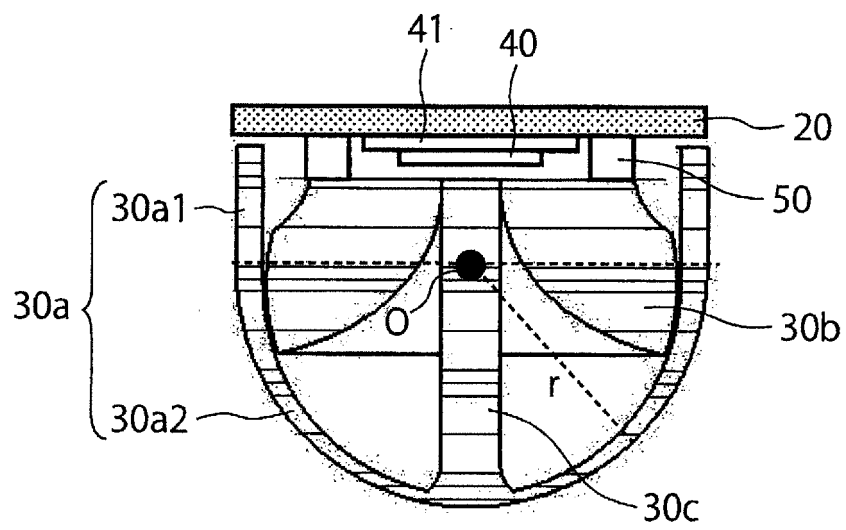


FIG. 2

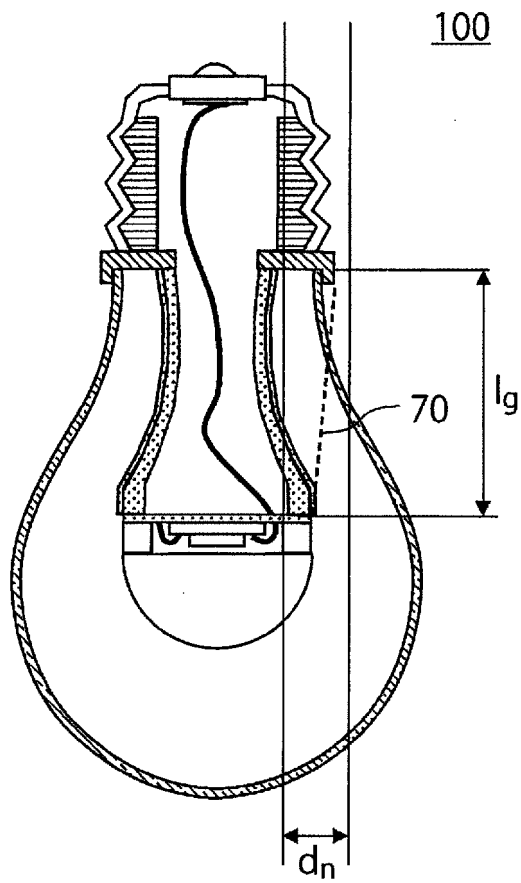


FIG. 3

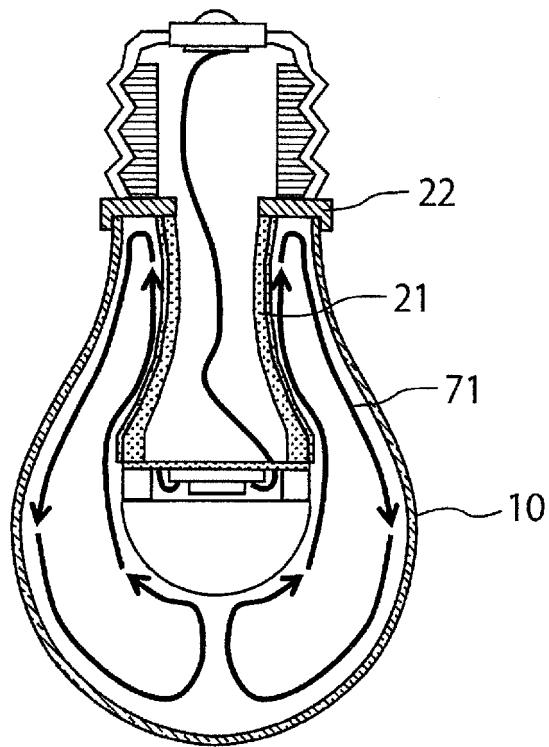


FIG. 4

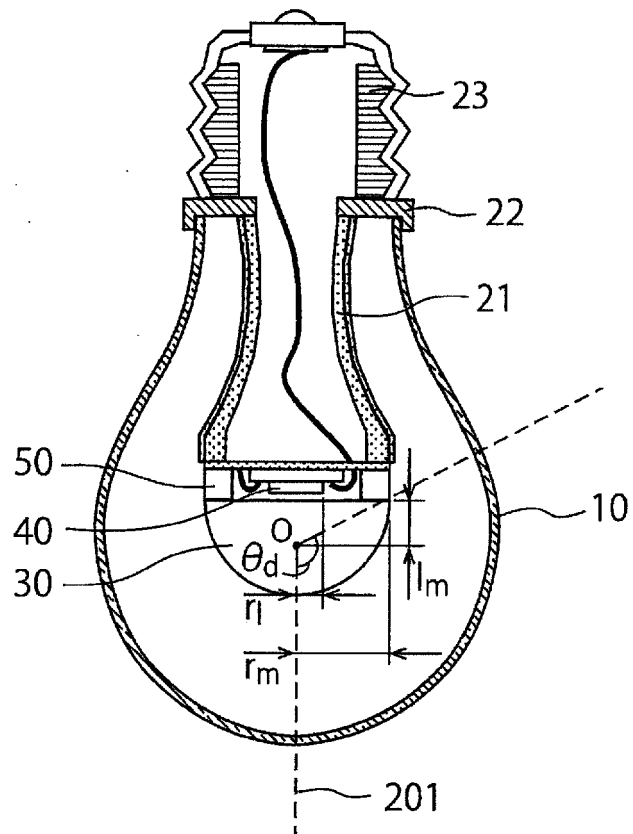


FIG. 5

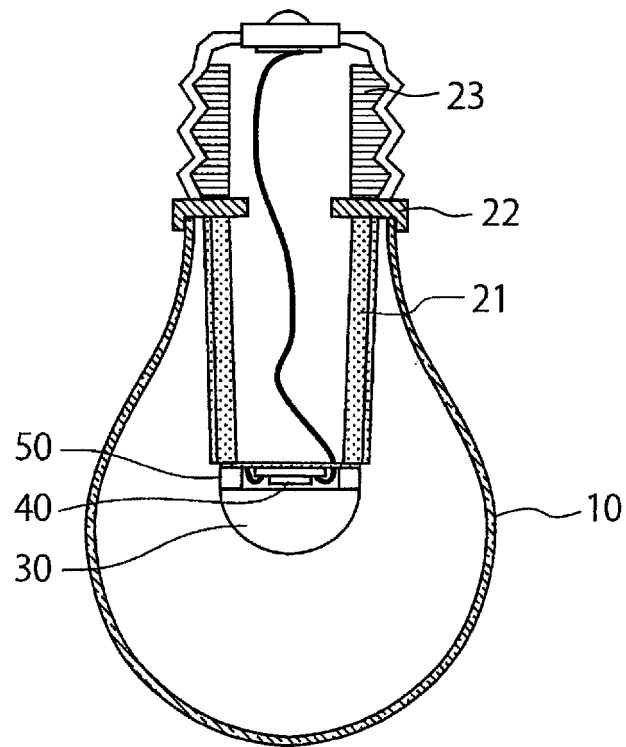


FIG. 6

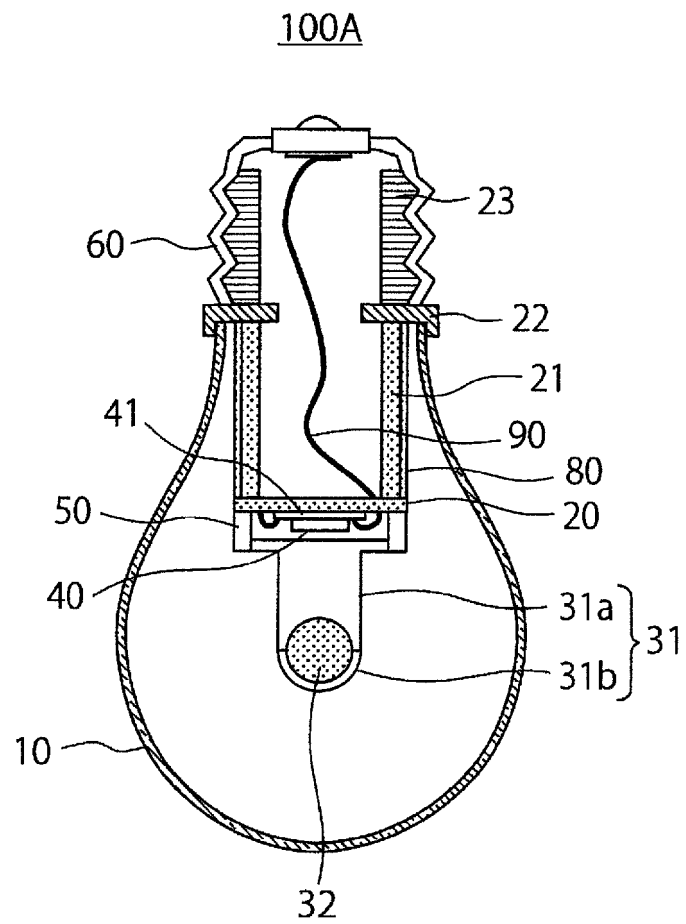


FIG. 7

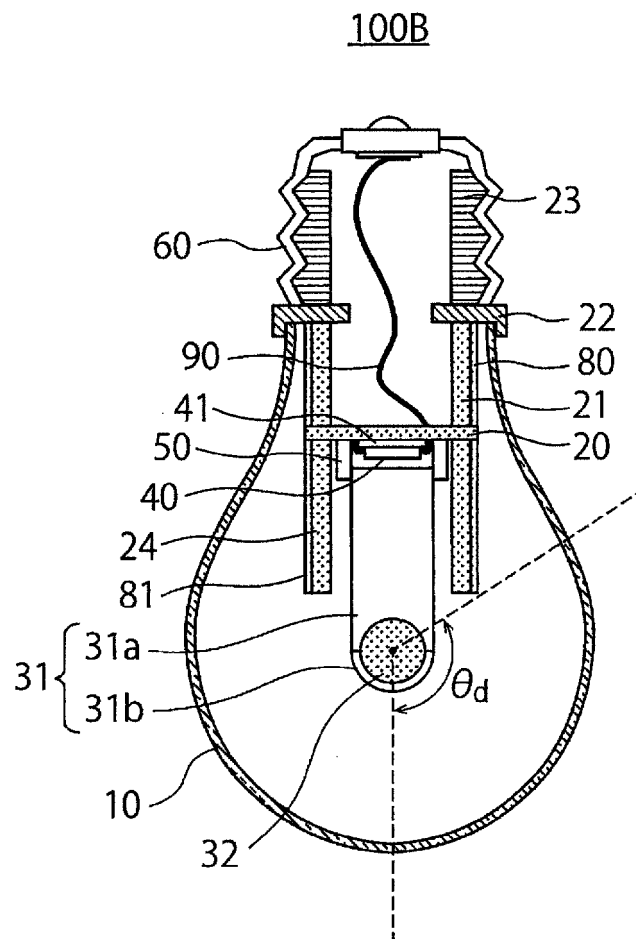


FIG. 8

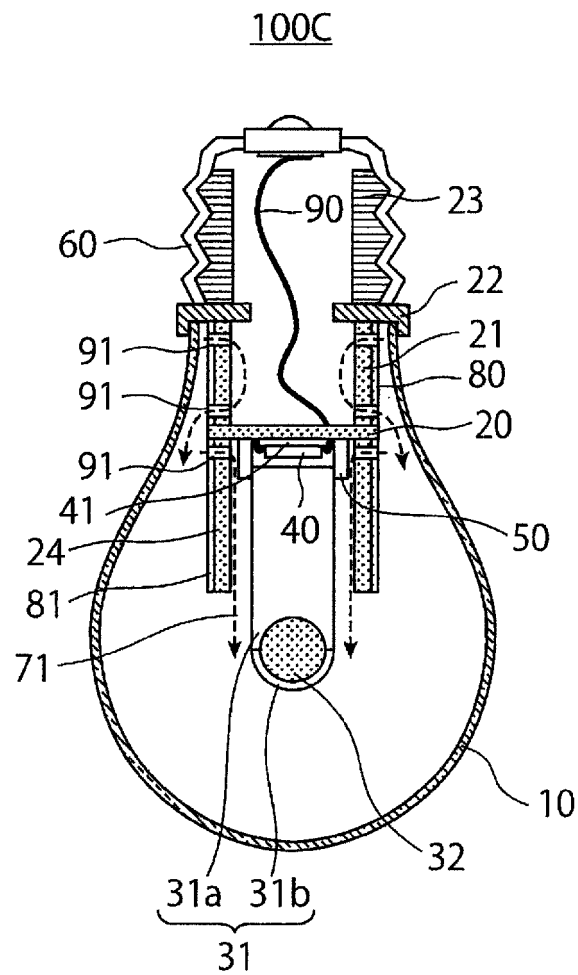
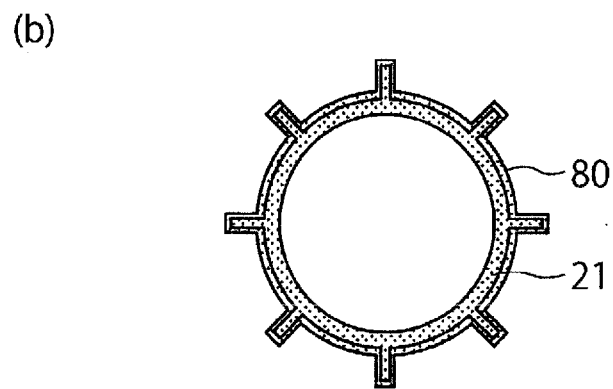
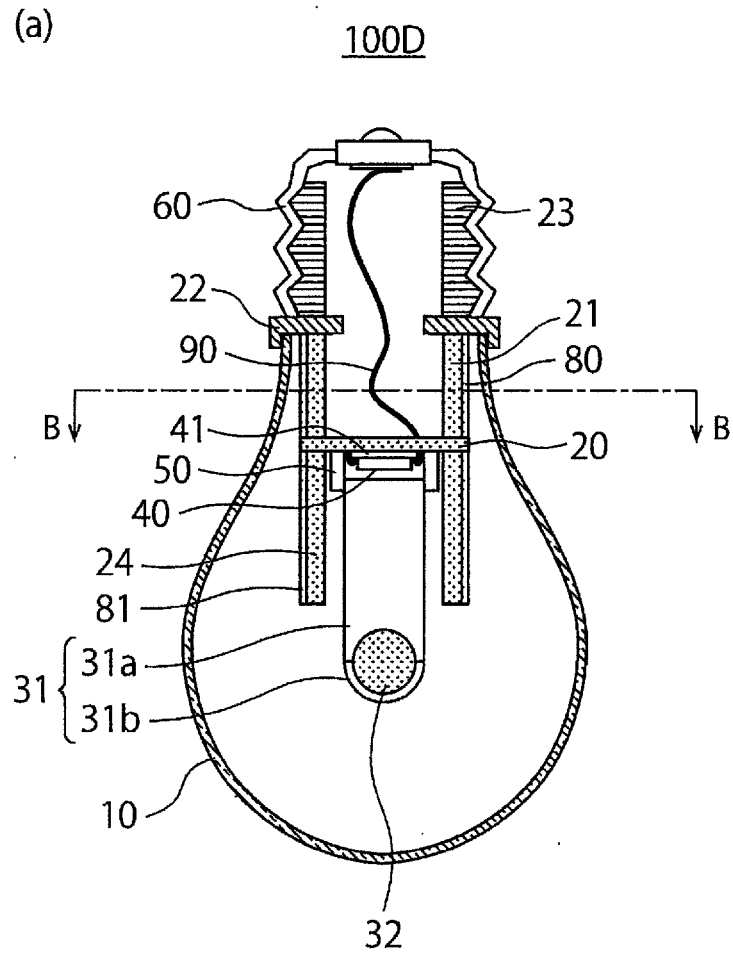


FIG. 9



CROSS SECTION TAKEN ALONG B-B

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/071234

A. CLASSIFICATION OF SUBJECT MATTER

F21S2/00(2006.01)i, F21Y101/02(2006.01)n

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)

F21S2/00, F21Y101/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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.
Y	JP 2013-33770 A (Panasonic Corp.), 14 February 2013 (14.02.2013), paragraphs [0370] to [0430]; fig. 37 to 40 & US 2013/0215625 A1 & EP 2636942 A1 & WO 2012/060106 A1 & CN 103052839 A	1-16, 21-40, 43-48
Y	JP 2012-221847 A (Sharp Corp.), 12 November 2012 (12.11.2012), paragraphs [0075] to [0091], [0100] to [0102]; fig. 1, 4 to 8 & US 2014/0001945 A1 & WO 2012/141226 A1 & CN 103459918 A	1-16, 21-40, 43-48
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☒ Further documents are listed in the continuation of Box C.
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Date of the actual completion of the international search
23 October, 2014 (23.10.14)Date of mailing of the international search report
04 November, 2014 (04.11.14)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/071234

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2013-4708 A (SGK Yugen Kaisha), 07 January 2013 (07.01.2013), paragraph [0031]; fig. 2 (Family: none)	1-16, 21-24
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REFERENCES CITED IN THE DESCRIPTION

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