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(71) Applicant: **Iwasaki Electric Co., Ltd.**
Tokyo 103-0002 (JP)

(72) Inventors:
- **MATSUZAKI Masayuki**
  Gyoda City
  Saitama 361-8505 (JP)
- **IMANARI Takayoshi**
  Gyoda City
  Saitama 361-8505 (JP)
- **SEKINE Moriyuki**
  Gyoda City
  Saitama 361-8505 (JP)
- **NAMIE Masayuki**
  Gyoda City
  Saitama 361-8505 (JP)

(74) Representative: **Shipp, Nicholas et al**
Kilburn & Strode LLP
20 Red Lion Street
London WC1R 4PJ (GB)

(54) LED LAMP

(57) The purpose of the present invention is to provide an LED lamp equipped with a novel cooling and heat radiation means. The lamp comprises: a plurality of LED elements (18); a light source support (14) extending along the axial line of a lamp while supporting the LED elements on the lateral surface; and a hermetically sealed glass container (6) surrounding the light source support and sealing in a low molecular weight gas as a cooling gas. The light source support surrounds a cooling gas flow channel along the axial line of the lamp and, in addition to a gas inlet and outlet located on both ends of the light source support, has gas inlets and outlets (26) between both ends.

Fig. 2A

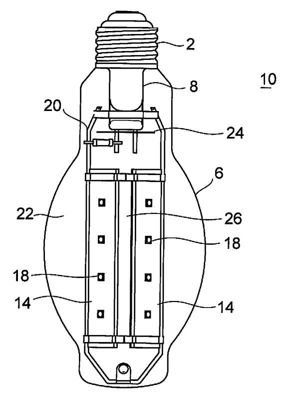
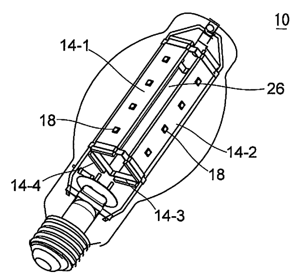


Fig. 2B



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Description

Technical Field

[0001] The present invention relates to an LED lamp.

Background Art

[0002] Generally, lighting lamps have been successively developed as incandescent light bulbs, fluorescent lamps, HID lamps, and LED lamps, and have been put to practical use. An LED lamp is a lamp using a light-emitting diode element as a light source. LED lamps have enabled the white light emission by the development of a blue LED element, and recently have been spread to be used as lighting lamps.

[0003] Figs. 1(A) to 1(C) are diagrams illustrating an example of currently widely sold LED lamps. These LED lamps 100 are generally lamps having the output of 10 watts or less (typically about 7 watts). As shown in Figs. 1(A) to 1(C), the lamps have various shapes, and basically include base 102, heat radiating portion 104, and globe 106. Heat radiating portion 104 is formed of aluminum die-casting, and in most cases, heat radiating fins are formed on the outer peripheral surface thereof. Globe 106 is made of translucent resin.

[0004] Unlike the incandescent light bulb, the fluorescent lamp, the HID lamp, and the like, an LED element is a semiconductor element, and therefore, is not needed to be disposed in a vacuum atmosphere or a predetermined gas atmosphere. Therefore, aluminum die cast portion 104 and globe 106 are fixed with a suitable adhesive. Therefore, the internal space formed by aluminum die cast portion 104 and globe 106 is not hermetically sealed from the outside of the lamp.

[0005] The present inventors know that the following related art literature related to the present invention is present.

Patent Literature 1: JP 2003-016805 A, "LIGHT AND METHOD OF MANUFACTURING THE SAME" (Publication Date: 2003/01/17), Applicant: Koichi Imai

Patent Literature 2: JP 2004-296245 A, "LED LAMP" (Publication Date: 2004/10/21), Applicant: Matsushita Electric Works, Ltd.

Patent Literature 3: JP 2010-135181 A, "LUMINATING DEVICE" (Publication Date: 2010/06/17), Applicant: Sharp Corporation

Patent Literature 4: International Publication WO 2012/095931 A1, "LAMP AND ILUMINATION DEVICE" (International Publication Date: 2012/07/19), Applicant: Panasonic Corporation

Patent Literature 5: JP 2012-156036 A, "LED LAMP" (Publication Date: 2012/08/16), Applicant: Iwasaki Electric Co., Ltd.

[0006] Compared with the LED lamp disclosed in the present application, the lamps disclosed in the related Patent Literature 1 to 5 are different in the following respects. First, the LED lamp disclosed in the present application covers that LED elements are hermetically sealed with a hermetically sealed glass container and that the hermetically sealed glass container is filled with a low molecular weight gas as a cooling and heat radiating means.

[0007] Patent Literature 1 illustrates resin and glass as the case member, and Patent Literature 1 discloses the effect that the internal light emitting diode is protected from the external environment when the glass is used, and furthermore, that any moisture does not remain and the glass does not fog up when a gas without any moisture (in the example, a nitrogen gas) is sealed in the glass container. However, here is no description or suggestion on the low molecular weight gas as a cooling and heat radiating means.

[0008] In Patent Literature 2, a valve for accommodating the LED lamp is formed of a resin material, and there is no description or suggestion on the hermetic sealing described in relation to the present invention.

[0009] In Patent Literature 3, the translucent cover is made of a polycarbonate resin, and the heat radiating portion is made of a metal such as aluminum. The lamp corresponds to the LED lamp illustrated in Fig. 1, and there is no description or suggestion on the hermetic sealing.

[0010] Patent Literature 4 discloses, "The lamp (100) according to the present invention is a lamp in which a gas is sealed, and includes globe (10) and LED module (20) which is housed in the globe (10) and which includes a base board (21) and LED (22) disposed on the base board (21). The gas in lamp (100) includes any of hydrogen, helium and nitrogen, and is sealed in globe (10) so as to surround the LED module (20)." (Abstract). In Patent Literature 4, there is no description on the cooling gas flow channel formed by the light source support, the cooling gas flowing therethrough, and the slit being the inlet and outlet of the cooling gas flow, and the like, which are disclosed in the present application.

[0011] Patent Literature 5 is an application filed by the present applicant, and is an application being the basis of the present invention. The difference between the present invention and the Patent Literature 5 will be described in detail below.

Summary of Invention

[0012] The LED element is a semiconductor element, and the temperature of the semiconductor junction and the element lifetime are closely related to each other. That is, the element life is a long term when the temperature of the junction during use is relatively low, but the element lifetime is suddenly shortened as the temperature increases. Therefore, in the LED lamp, the lamp lifetime is shortened and the lamp illuminance is also deteriorated when the temperature of the LED element is high.
[0013] The cooling and heat radiating means is an important matter in an electronic device using a semiconductor device, and in the same way, the cooling and heat radiating means is also an important matter in the LED lamp.
[0014] Therefore, the present applicant has suggested the following idea by Patent Literature 5. That is, the cooling gas (low molecular weight gas) is encapsulated in hermetically sealed lamp configurations of the lamp. Inside the lamp, a light source support having a shape longer in the lamp axial line direction is disposed, and mounts a plurality of LEDs on its periphery. Inside the light source support, a through-hole is formed along the lamp axial line as a cooling gas flow channel to cool the LEDs also from the back surface efficiently. For this idea, a constant cooling effect is confirmed to be present, and is shown in the graph of Fig. 6 in Patent Literature 5.
[0015] After the application of Patent Literature 5, based on the idea suggested therein, the present inventors have continued the research and development of LED lamp configuration including an improved cooling and heat radiating means.
[0016] Based on the results of continued research and development, the present invention has an object to provide an LED lamp including a novel cooling and heat radiating means.
[0017] A LED lamp of the present invention comprises a plurality of LED elements; a light source support supporting the LED elements on a side surface, extending along a lamp axial line; and a hermetically sealed glass container surrounding the light source support and hermetically sealing to encapsulate a low molecular weight gas as a cooling gas therein, wherein the light source support surrounds a cooling gas flow channel along the lamp axial line and has a gas inlet and outlet between the end portions of the light source support in addition to a gas inlet and outlet at both end portions thereof.
[0018] Further, with reference to the above described LED lamp, wherein the low molecular weight gas may include any of a helium gas, a hydrogen gas, and a neon gas, or a mixed gas of any combination of these.
[0019] Further, with reference to the above described LED lamp, wherein the light source support may include a plurality of light source support pieces disposed so as to surround the cooling gas flow channel, the plurality of light source support pieces may be disposed so as to form a n-gon (n = 3 or more) as viewed in cross section perpendicular to the lamp axial line, and the gas inlet and outlet disposed between the end portions of the light source support may include a slit between adjacent light source supports.
[0020] Further, with reference to the above described LED lamp, wherein the light source support may be a rod-shaped body extending along the lamp axial line, the cooling gas flow channel may be formed in a through hole formed along the lamp axial line in the light source support, and the gas inlet and outlet between the end portions of the light source support may be an opening leading from the side surface to the through hole of the light source support.
[0021] Further, with reference to the above described LED lamp, wherein a mounting board on which the plurality of LEDs is mounted may be fixed to the light source support.
[0022] Further, with reference to the above described LED lamp, wherein a mounting board on which the plurality of LEDs is mounted may be fixed to the light source support, and the mounting board may be made of a metal core board.
[0023] Further, with reference to the above described LED lamp, wherein the light source support may include a member having a good thermal conductivity containing at least one of aluminum, copper, and a heat conductive resin.
[0024] Further, with reference to the above described LED lamp, wherein the light source support may include a plurality of light source support pieces disposed so as to surround the cooling gas flow channel, the plurality of light source support pieces may be disposed so as to form a n-gon (n = 3 or more) as viewed in cross section perpendicular to the lamp axial line, and the gas inlet and outlet disposed between the end portions of the light source support may include an opening slit or a mesh hole leading from a surface to the cooling gas flow channel of the light source support.
[0025] Further, with reference to the above described LED lamp, wherein the light source support may have shapes expanded at both the end portions, and a cross-sectional area of the cooling gas flow channel may be relatively narrower at a central portion as compared to both the end portions.
[0026] Further, with reference to the above described LED lamp, wherein the light source support pieces may have a thickness of a central portion formed thicker as compared to both the end portions, and a cross-sectional area of the cooling gas flow channel may be relatively narrower at a central portion as compared to both the end portions.
[0027] Further, with reference to the above described LED lamp, the lamp further may comprise a heat transfer device inside a top portion of the hermetically sealed glass container opposite to the base, the heat transfer device fixed to the light source support and made of a thermal conductivity resin.
[0028] Further, with reference to the above described LED lamp, the lamp further may comprise an additional heat

radiator in a top portion outside the hermetically sealed glass container, having a thermal conductivity relationship with the heat transfer device across the hermetically sealed glass container.

[0029] Further, with reference to the above described LED lamp, the lamp further may comprises a gas flow acceleration fan in the vicinity of an upper end, a lower end, or the both of the light source support.

[0030] Further, with reference to the above described LED lamp, wherein a nitrogen gas may be encapsulated in addition to the low molecular weight gas inside the hermetically sealed glass container.

[0031] According to the present invention, it is possible to provide an LED lamp including a novel cooling and heat radiating means.

Brief Description of Drawings

[0032]

Figs. 1(A) to 1(C) are diagrams illustrating an example of currently widely sold LED lamps.

Figs. 2(A) and 2(B) are views showing an example of an LED lamp according to a first embodiment of the present invention. Here, Fig. 2(A) is a front view of the LED lamp, and Fig. 2(B) is a perspective view seen obliquely from below so that the positional relation of the four light source support pieces can be seen.

Fig. 3A is a diagram illustrating the light source support to be used in the LED lamp shown in Figs. 2(A) and 2(B).

Fig. 3B is a diagram illustrating the light source support according to a second embodiment of the present invention.

Fig. 4A is a diagram illustrating the flow of the cooling gas flow when there is no slit between the light source support pieces proposed in the Patent Literature 5.

Fig. 4B is a diagram illustrating the flow of the cooling gas flow when there is a slit between the light source support pieces according to the first embodiment shown in Figs. 2(A) and 2(B).

Fig. 5A is a graph comparing the LED cooling effects due to the presence or absence of the slits between the light source support pieces when the lamp is lit vertically (BD).

Fig. 5B is a graph comparing the LED element temperatures due to the presence or absence of the slits between the light source support pieces when the lamp is lit horizontally (BH).

Fig. 6A is a graph comparing the LED element temperatures due to the vertical lighting (BD) and the horizontal lighting (BH) when there is a slit between the light source support pieces.

Fig. 6B is a graph comparing the LED element temperatures due to the vertical lighting (BD) and the horizontal lighting (BH) when there is no slit between the light source support pieces.

Fig. 7 is a graph comparing the LED element temperatures in the case of the horizontal lighting (BH) with slits between the light source support pieces and in the case of the vertical lighting (BD) without slits.

FIG. 8A is a diagram showing an example where an opening is disposed between both the end portions of the light source support according to a third embodiment of the present invention.

Fig. 8B is similarly a diagram illustrating an example where the light source support is formed in a lattice or mesh shape.

Fig. 9 is a flowchart of a method of manufacturing an LED lamp according to the present embodiment, and on the right side of each step, a simple diagram of a lamp in the corresponding stage is shown.

Fig. 10A is a diagram illustrating a light source support having expanded end portions according to a fourth embodiment of the present invention.

Fig. 10B is similarly a diagram illustrating a light source support where the thickness of the middle portion is thickened.

Fig. 11 is a diagram illustrating a heat transfer device according to a fifth embodiment and an additional heat radiator according to a sixth embodiment of the present invention.

Fig. 12 is a diagram illustrating an example where a cooling air driving fan is disposed near the end portion of the light source support according to a seventh embodiment of the present invention.

Description of Embodiments

[0033] In the following, the embodiment of an LED lamp according to the present invention will be described in detail with reference to the accompanying drawings. It should be noted that in the figures, the same elements will be denoted by the same reference numerals, and an overlapping description will be omitted. In addition, it should be aware that the embodiments to be described below are exemplary, and are not intended to limit the scope of the present invention.

[First Embodiment]

(Configuration of LED Lamp)

[0034] Figs. 2(A) and 2(B) are views showing an example of a LED lamp according to the first embodiment of the present invention. Here, Fig. 2(A) is a front view of the LED lamp, and Fig. 2(B) is a perspective view seen obliquely from below so that the positional relationship of the four light source support pieces can be seen. This LED lamp 10 primarily targets a higher output LED lamp of about 20 watts, rather than a lower output LED lamp of about 7 watts, currently widely advertised and sold, described in Fig. 1. Therefore, the cooling and heat radiating means becomes a furthermore important consideration matter.

[0035] LED lamp 10 shown in Fig. 2(A) includes a plurality of LED elements 18 disposed inside outer bulb 6, one end of which is hermetically sealed with base 2. A plurality of LED elements 18 is mounted at appropriate intervals on light source support 14 to be fixed.

[0036] Furthermore, the light source support 14 is positioned and supported in an appropriate place inside outer bulb 6 by support column 20 extending from stem 8 fixed to one end of outer bulb 6. Optionally, a part of support column 20 adjacent to light source support 14 is covered by an insulating tube (not shown), whereby the electrical insulation between light source support 14 and support column 20 is secured.

[0037] Furthermore, heat shielding member 24 may be disposed inside outer bulb 6 near base 2. Heat shielding member 24 is formed of, for example, ceramics, a metal plate, a mica plate, and the like. The function of heat shielding member 24 will be described below in relation to the manufacturing method shown in Fig. 9.

[0038] A low molecular weight gas is encapsulated in internal space 22 of outer bulb 6. In the present application document, "low molecular weight gas" means a gas having large specific heat and good thermal conductivity, typically helium gas. Furthermore, the gas may be neon gas, hydrogen gas, or a mixed gas of these. In particular, hydrogen gas has high reactivity; therefore, a mixed gas of hydrogen gas and helium gas with reduced reactivity may be used. In the case of using hydrogen gas or helium gas, see also the eighth embodiment described below.

(Description of Each Component)

[0039] Each element of LED lamp 10 shown in Fig. 2(A) will be briefly described.

[0040] Base 2 may be a screw type (E type) or a plug type used in incandescent light bulbs and HID lamps. Outer bulb 6 is, for example, a BT tube made of translucent hard glass such as borosilicate glass. However, it may be any shape. Outer bulb 6 may be any one of transparent type or diffusing type (frosted glass type). As with the known incandescent lamp and HID lamp, the gap between base 2 and outer bulb 6 is hermetically sealed, and the space between the outer bulb internal space and the external space is in a hermetically sealed state.

[0041] As shown in Fig. 2(B), this LED lamp 10 includes a light source support 14 containing four light source support pieces 14-1 to 14-4, and one or two or more LED elements 18 are mounted on each light source support piece.

[0042] Fig. 3A is a diagram illustrating the light source support 14. The outer shape of light source support pieces 14-1 to 14-4 is a plate-like body, and the light source support piece is made of a material having good thermal conductivity, such as copper, aluminum, and a thermal conductivity resin. The thermal conductivity resin is a resin having a high coefficient of thermal conductivity by being mixed with the metal powder, or metal piece.

[0043] Four light source support pieces 14-1 to 14-4 are disposed so as to generally form a rectangle as viewed in the axial direction cross section. Furthermore, the adjacent light source support pieces are not connected to each other, and are disposed at intervals of slit (gap) 26. Light source support 14 shown in the figure is disposed so that the axial direction cross section forms a rectangle when the four light source support pieces are viewed in the axial direction cross section; but not limited to this. That is, light source support 14 may be disposed with three light source support pieces so that the axial direction cross section forms a triangle, and may be disposed with any number (n) of light source support pieces so that the axial direction cross section forms any polygon (n-gon).

[0044] The power supply to each of LED elements 18 is performed by lead wires (not shown) connecting the LED elements in series. When light source support 14 is made of a good electrical conductor, the light source support may also be used as a power supply line.

[Second Embodiment]

[0045] Fig. 3B is a diagram illustrating light source support 14 according to the second embodiment. As compared to the light source support according to the first embodiment, the second embodiment is different in that LED elements 18 are mounted on mounting board 16, and that mounting board 16 is fixed on light source support 14.

[0046] As shown in the figure, mounting boards 16 are fixed on the outer peripheral side surfaces of light source support 14. Optionally, thermal conductive sheets (not shown) may be disposed by being interposed between the outer peripheral side surfaces of light source support 14 and mounting board 16. If the cross-sectional shape of light source support 14 is a n-gon, on the n outer peripheral side surfaces, respective mounting boards 16 are fixed. On each of mounting boards 16, one or two or more LED elements 18 are mounted.

[0047] Mounting board 16 includes a printed wiring board, and circuit patterns necessary for supplying power to the LED elements are formed in the printed wiring board. Mounting board 16 is preferred to have a relatively thin thickness, or to be formed as a metal core board so as to enhance the heat radiating and cooling effect of LED element 18. In the technical field of the printed wiring board, the metal core board is a known technology. Due to the good thermal conductivity of metal, a large heat radiating and cooling effect can be expected.

[0048] In the same manner as in the first embodiment, the adjacent light source support pieces are not connected to each other, and are disposed at intervals of slit (gap) 26. Furthermore, any number of the light source support pieces may be disposed so that they form any polygon.

[Arrangement and Cooling Effect of Light Source Support]

(Arrangement of Light Source Support)

[0049] In the first embodiment and the second embodiment, it is described that the adjacent light source support pieces are not connected to each other, and are disposed at intervals of slit (gap) 26. The reason is as follows.

[0050] The present applicant has suggested the idea where the adjacent light source support pieces are connected to each other in the Patent Literature 5 (see Fig. 3 of Patent Literature 5). Fig. 4A is a diagram illustrating the flow of the cooling gas flow when there is no slit by mutually connecting these light source support pieces. As shown in the figure, gas flow channel 15 in the axial direction is formed by being surrounded by four light source support pieces 14-1 to 14-4. Light source support 14 is raised to a high temperature due to the heat generation of LED elements 18, and the cooling gas in gas flow channel 15 heated by the high-temperature light source support moves upward, becomes warm gas stream 23-2, and is released inside the lamp outer bulb from the upper end of the gas flow channel. On the other hand, new gas stream 23-1 flows into the gas flow channel from the lower end of the gas flow channel. The back surface of light source support 14 is effectively cooled by such a chimney effect. LED element 18 is cooled by the cooling gas surrounding the front surface thereof. In addition to this, LED element 18 is effectively cooled on the back surface by light source support 14. As for this idea, a certain cooling effect is confirmed to be present, and is shown graphically in Fig. 6 of Patent Literature 5.

[0051] However, after the filing of Patent Literature 5, the present inventors have continued the research and development of LED lamp having an improved cooling and heat transfer means based on this idea. As a result, adjacent light source support pieces 14 are not connected to each other, and are disposed at intervals of slit (gap) 26, whereby the present inventors have found that the cooling effect is further increased.

[0052] Fig. 4B is a diagram illustrating the flow of the cooling gas flow when light source support pieces 14-1 to 14-4 have a slit in-between. The larger cooling effect is thought to be caused by that gas stream 23-3 flowing in to or flowing out from gas flow channel 15 through the slit increases in addition to gas streams 23-1 and 23-2 shown in Fig. 4A.

(Cooling Effect)

[0053] The difference in cooling effect by the presence or absence of the slit, considering the lamp lighting direction (vertical lighting or horizontal lighting) will be described with reference to the graphs of Figs. 5A to 6B. It should be noted that although the experiment of vertical lighting is performed in BD where the base is positioned on the lower side, the same effect can be expected even in BU where the base is positioned on the upper side.

[0054] Table 1 is the experimental data. This experiment was performed under the following conditions.

Light source support: one piece is 140 mm length × 25 mm width × 3 mm thick aluminum plate, four pieces
Size of slit (distance between adjacent light source support pieces): 3.5 mm
LED specification: 20 watts × 4 sheets

Table 1: Cooling Effect by the Presence or Absence of the slit, considering the Lamp Lighting Direction

BD: Vertical Lighting BH: Horizontal Lighting						
	LED Drive Voltge Vf (V)	**LED Drive Current If (A)**	**LED Drive Power P(W)**	**TC-25°C Conversion Value (°C)**	**LED Case Temp. TC (°C)**	**Ambient Temp. (°C)**
Model I: (BD, with slits)	**156.7**	**0.125**	**20**	**75.2**	**77.2**	**27**
	157.0	**0.191**	**30**	**104.4**	**107.4**	**28**
	157.0	**0.255**	**40**	**131.0**	**135.0**	**29**

(continued)

						BD: Vertical Lighting BH: Horizontal Lighting
	LED Drive Voltge Vf (V)	LED Drive Current If (A)	LED Drive Power P(W)	TC-25°C Conversion Value (°C)	LED Case Temp. TC (°C)	Ambient Temp. (°C)
Model II: (BD, without slits)	155.5	0.128	20	91.0	96.0	30
	155.6	0.191	30	122.4	125.4	28
	155.5	0.257	40	152.5	155.5	28
Model III: (BH, with slits)	156.6	0.127	20	86.1	89.1	28
	157.3	0.190	30	111.7	114.7	28
	157.3	0.222	35	127.0	131.0	29
Model IV: (BH, without slits)	155.3	0.130	20	100.4	102.4	27
	155.7	0.191	30	128.3	130.3	27
	155.2	0.224	35	148.7	150.7	27

[0055] Based on the data in Table 1, the magnitude of the cooling effect was compared and examined between the lighting direction (BD and BH) and the presence and absence of the slit. That is, the magnitude of the cooling effect was compared and examined for the following models listed in the left column of Table 1:

Model I: (BD, with slits);

Model II: (BD, without slits);

Model III: (BH, with slits); and

Model IV: (BH, without slits).

[0056] Fig. 5A is a graph comparing the LED cooling effects due to the presence or absence of the slits between the light source support pieces when the lamp is lit vertically (BD). Fig. 5B is a graph comparing the LED element temperatures due to the presence or absence of the slits between the light source support pieces when the lamp is lit horizontally (BH).

[0057] In case of the vertical lighting (BD) shown in Fig. 5A, for example, when the LED drive power is 30 watts, whereas the case temperature of the LSI element without slits (▲ in graph) is 122.4°C in TC-25°C conversion value, the case temperature with slits (□) is as low as 104.4°C. When the LED drive power is in the range of 20 to 40 watts, "with slits (□) in Model I" had lower temperatures and the cooling effect was larger as compared to "without slits (▲) in Model II".

[0058] In case of the horizontal lighting (BH) shown in Fig. 5B, for example, when the LED drive power is 30 watts, whereas the case temperature of the LSI element without slits (▲) is 128.3°C in TC-25°C conversion value, the case temperature with slits (□) is as low as 111.7°C. When the LED drive power is in the range of 20 to 40 watts, "with slits (□) in Model III" had lower temperatures and the cooling effect was larger as compared to "without slits (▲) in Model IV".

[0059] Consequently, it was found that irrespective of the lighting direction (BD or BH), "with slits (□)" has a larger cooling effect and the temperature of the LED element 18 is kept lower as compared to "without slits (▲)". For the temperature of the LED element, there was a following relation: Model I, III < Model II, IV (meaning that the right side has a higher temperature).

[0060] Fig. 6A is a graph comparing the LED cooling effects due to the vertical lighting (BD) and the horizontal lighting (BH) when there is a slit. Fig. 6B is a graph comparing the LED cooling effects due to the vertical lighting (BD) and the horizontal lighting (BH) when there is no slit.

[0061] In case of the "with slits" shown in Fig. 6A, for example, when the LED drive power is 30 watts, whereas the case temperature of the LSI element in the horizontal lighting (BH) is 111.7°C in TC-25°C conversion value, the case temperature in the vertical lighting (BD) is as low as 104.4°C. When the LED drive power is in the range of 20 to 40 watts, the vertical lighting (BD) in Model IV had lower temperatures and the cooling effect was larger as compared to the horizontal lighting (BH) in Model III.

[0062] In case of the "without slits" shown in Fig. 6B, for example, when the LED drive power is 30 watts, whereas the case temperature of the LSI element in the horizontal lighting (BH) is 128.3°C in TC-25°C conversion value, the case temperature in the vertical lighting (BD) is as low as 122.4°C. When the LED drive power is in the range of 20 to 40 watts, the vertical lighting (BD) in Model II had lower temperatures and the cooling effect was larger as compared to the horizontal lighting (BH) in Model IV.

[0063] Consequently, it was found that regardless of the presence or absence of the slit, the vertical lighting (BD) has a larger cooling effect and the temperature of the LED element 18 is kept lower as compared to the horizontal lighting (BH). For the temperature of the LED element, there was a following relation: Model (I, II) < Model (III, IV).

[0064] Fig. 7 is a graph comparing the LED element temperatures between Model III (in the case of the horizontal lighting (BH) with slits) and Model II (in the case of the vertical lighting (BD) without slits). For example, when the LED drive power is 30 watts, whereas the case temperature of the LSI element in Model III is 122.4°C in TC-25°C conversion value, the case temperature in Model II is as low as 111.7°C. When the LED drive power is in the range of 20 to 40 watts, Model II had lower temperatures and the cooling effect was larger as compared to Model III. For the temperature of the LED element, there was a following relation: Model II < Model III.

[0065] To summarize the above results, the following are obtained.
From the results of Figs. 5A and 5B, Model (I, III) < Model (II, IV) is obtained, from the results of Figs. 6A and 6B, Model (I, II) < Model (III, IV) is obtained, and from the result of Fig. 7, Model II < Model III is obtained.
Therefore, the LSI element temperature was found to increase in the following order. That is, the LED element temperature is kept higher as the order moves to the right side, and the temperature of LED element 18 is kept lower as the order move to the left side, and the cooling effect was found to be large.
Model I (with slits, BD) < Model II (with slits, BH) < Model III (without slits, BD) < Model IV (without slits, BH)
As a result, it was found that the first factor contributing to the cooling is "with slits", and that the second factor is the "vertical lighting (BD)". The lighting manner relating to the second factor is determined, in many cases, by the building, the lighting area, the lighting fixture, the customer needs, and the like where the lamp is installed. Therefore, it is important that the light source support is being "with slits".

[Third Embodiment]

[0066] From the "with slits" being the first factor, the following technological knowledge was obtained: "the cooling effect on the LED elements is further improved by providing cooling gas inlets and outlets also between the end portions of the light source support, in addition to the cooling gas inlets and outlets at both the end portions of light source support 14 forming gas flow channel 15".

[0067] FIG. 8A is a diagram showing an example where openings are disposed between both the end portions of the light source support according to the third embodiment of the present invention. Fig. 8B is similarly a diagram illustrating an example where light source support 14 is formed in a lattice or mesh shape. Light source support 14 shown in Fig. 8A does not include any slit mutually between light source support pieces, and includes a plurality of openings 26a as the cooling gas inlets and outlets also between the end portions, in addition to the cooling gas inlets and outlets at both the end portions. The size, the shape, and the number of openings 26a may be any desired level. It should be noted that the slit may be disposed mutually between the light source support pieces, and a plurality of openings 26a may be disposed as the cooling gas inlets and outlets also between the end portions.

[0068] Light source support 14 shown in Fig. 8B is formed in a lattice or mesh shape, and includes a plurality of openings or mesh holes 26b as the cooling gas inlets and outlets also between the end portions, in addition to the cooling gas inlets and outlets at both the end portions. The size, the shape, and the number of the openings or mesh holes 26b may be any desired level. It should be noted that the slit may be disposed mutually between the light source support pieces, and a plurality of openings or mesh holes 26a may be disposed as the cooling gas inlets and outlets also between the end portions.

[0069] The light source support forming the cooling gas flow channel is not limited to the light source support where a plurality of light source support pieces is arranged in a rectangle or polygon as viewed in cross-section. The cooling gas flow channel is substantially sufficient to be formed along the lamp axial line. As viewed in cross-section, one light source support having the cross-section of a circle, an ellipse, and the like may be used. The cooling gas inlets and outlets between both the end portions are substantially sufficient if the inlets and outlets have the function of gas communication between the cooling gas inside the outer tube and the cooling gas in the cooling gas flow channel formed by the light source support. The preferred opening area between both the end portions (the total area of the slits, openings, mesh holes, and the like) relative to the total surface area of the gas flow channel, that is, the preferred opening ratio, is left to the research and development in the future.

(Method of Manufacturing LED Lamp)

[0070] Fig. 9 is a flowchart of the method of manufacturing the LED lamp according to the present embodiment, and on the right side of each step, a simple diagram of the lamp in the corresponding stage is shown.
[0071] In the mount assembly process in step S1, LED element 18 is fixed to light source support 14, the light source support is attached to support column 20 to form a mount, and stem 8 is attached thereto.
[0072] In the sealing process of step S2, the mount is inserted inside the outer bulb of outer bulb 6, and stem 8 to which the mount is attached and outer bulb 6 are sealed by heating with a burner to seal hermetically.
[0073] In the exhausting process of step S3, the inside of the outer bulb already sealed is once evacuated to a vacuum state through the exhaust pipe. Then, a low molecular weight gas is encapsulated, and chipped off (the exhaust pipe is sealed by being dissolved on the burner).
[0074] In the base-attaching process in step S4, the top portion and the side portion of base 2 are soldered.
[0075] Through the lighting test and inspection in step S5, LED lamp 10 is completed.
[0076] Here, in steps S2 to S4, the mounting portion, the stem, and the like of the outer bulb are heated to a high temperature of near 1000°C by a burner. Heat shielding member 24 (see Figs. 2(A) and 2(B)) is disposed between the base mounting portion of the outer bulb and LED elements 18 so that this heat does not damage LED elements 18 inside the outer bulb by not being transmitted to LED elements 18.

[Other Embodiments]

[0077] Furthermore, the present invention can employ other embodiments as follows.

(Fourth Embodiment)

[0078] Fig. 10A is a diagram illustrating a light source support having expanded end portions according to the fourth embodiment of the present invention. Fig. 10B is similarly a diagram illustrating a light source support where the thickness of the middle portion is thickened. In the fourth embodiment, the cooling gas flow channel formed by the light source support has a smaller (narrower) cooling gas flow channel cross-sectional area in the central portion, as compared to the cooling gas flow channel cross-sectional area at both the end portions. Light source support 14c shown in Fig. 10A has a relatively narrower central portion by both the end portions being expanded to trumpet-shape. Light source support 14d shown in Fig. 10B has a relatively narrower central portion by the thickness of the middle portion of each support piece being made thicker than the thickness at both the end portions. The cooling gas flow channel cross-sectional area in the central portion is narrowed, whereby it is expected that the gas flow is accelerated in the central portion, and that the cooling effect is increased.

(Fifth and Sixth Embodiments)

[0079] Fig. 11 is a diagram illustrating a heat transfer device 28 according to the fifth embodiment and an additional heat radiator 30 according to the sixth embodiment of the present invention. In the fifth embodiment, as shown in Fig. 11 (A), heat transfer device 28 is formed inside the outer bulb, whereby further improvement of cooling and heat radiating performance is aimed. Specifically, a thermal conductive resin is poured into the outer bulb, and cured to form heat transfer device 28. During the lamp manufacturing, although the vicinity of base 2 of outer bulb 6 is heated and exposed to a high temperature, the top part of the outer bulb is not exposed to the heat by the effect of heat shielding member 24 and the like. Therefore, the preformed heat transfer device 28 is not affected by the heat in the subsequent manufacturing process.
[0080] During the prototyping stage, heat transfer device 28 was created by using a thermal conductive resin where the carbon fiber is mixed to silicon. However, other thermal conductive resins (resins mixed with metal powder or metal pieces) may be used. The end portion of light source support 14 is directly fixed to the heat transfer device 28. In this case, so as to ensure the inlets and outlets of the cooling gas flow at the end portions of light source support 14, for example, a notch, a hole, and the like are disposed at the end portions of the light source support, or the end portion is made a plurality of legs shaped, whereby the inlets and outlets of the gas flow (not shown) are not blocked. The end portion of light source support 14 is directly fixed to heat transfer device 28, whereby the heat generated in LED element 18 is efficiently thermally conducted from light source support 14 to heat transfer device 28, and the cooling and heat radiating effect is improved.
[0081] The sixth embodiment is an example where additional heat radiator 30 is additionally adopted in addition to the fifth embodiment. As shown in Fig. 11(B), additional heat radiator 30 is attached to the outside of the outer bulb for heat transfer device 28 of the fifth embodiment. Additional heat radiator 30 is formed so as to meet the external shape of the top portion of the outer bulb, and is press-fitted or fixed with a suitable adhesive to the top portion of the outer

bulb. The material of additional heat radiator 30 may be the material having good thermal conductivity such as the same thermal conductivity resin as in heat transfer device 28. Heat transfer device 28 inside the outer bulb and additional heat radiator 30 outside the outer bulb have a thermal conductive relationship through the outer bulb glass, and therefore, the heat of heat transfer device 28 is efficiently released to the outside air through additional heat radiator 30.

(Seventh Embodiment)

[0082] Fig. 12 is a diagram illustrating an example where a cooling air driving fan is disposed near the end portion of the light source support according to the seventh embodiment of the present invention. Gas flow acceleration fan 32 may be disposed at the cooling gas inlet in the lower end portion of light source support 14. Gas flow acceleration fan 32 may be disposed at the gas outlet in the upper end portion of light source support 14, and may be disposed in both the end portions. By the action of gas flow acceleration fan 32, the cooling gas passing through cooling gas flow channel 15 is accelerated, and the cooling effect is further increased.

(Eighth Embodiment)

[0083] The eighth embodiment, although not shown, is an example of encapsulating another gas, in addition to the low molecular weight gas to be encapsulated in internal space 22 of outer bulb 6. Hydrogen gas or helium gas of the low molecular weight gas has small molecules, and therefore the phenomenon that the gas gradually escapes from outer bulb 6 to the outside has been observed when the lamp is used for a long time. When the cooling gas escapes, the amount of the cooling gas in the outer bulb is decreased, then the temperature of LED element 18 is increased. To prevent this, when hydrogen gas or helium gas is used, it is preferred that the gas is mixed with a gas having relatively large molecules difficult to escape to outside the outer bulb (typically nitrogen gas) to be encapsulated.

[Conclusion]

[0084] As described above, although the embodiments of the LED lamp according to the present invention are described, these are exemplary, and are not intended to limit the present invention. The technological scope of the present invention is determined by the scope of the appended claims.

Reference Signs List

[0085]

1	lamp
2	base
6	outer bulb
8	stem
10	lamp
14, 14a to 14d	light source support
14-1 to 14-4	light source support piece
15	cooling gas flow channel
16	mounting board
18	LED element
20	support column
22	internal space
23	gas flow
24	heat shielding member
26a	opening
26b	mesh hole
28	heat transfer device
30	additional heat radiator
32	gas flow acceleration fan
100	lamp
102	base
104	aluminum die-cast portion
104	heat radiating portion
106	globe

BD	vertical lighting
BH	horizontal lighting

Claims

1. A LED lamp comprising:

    a plurality of LED elements;
    a light source support supporting the LED elements on a side surface, extending along a lamp axial line; and
    a hermetically sealed glass container surrounding the light source support and hermetically sealing to encapsulate a low molecular weight gas as a cooling gas therein,
    wherein the light source support surrounds a cooling gas flow channel along the lamp axial line and has a gas inlet and outlet between the end portions of the light source support in addition to a gas inlet and outlet at both end portions thereof.

2. The LED lamp according to claim 1,
wherein the low molecular weight gas includes any of a helium gas, a hydrogen gas, and a neon gas, or a mixed gas of any combination of these.

3. The LED lamp according to claim 1 or 2,
wherein the light source support includes a plurality of light source support pieces disposed so as to surround the cooling gas flow channel,
the plurality of light source support pieces is disposed so as to form a n-gon (n = 3 or more) as viewed in cross section perpendicular to the lamp axial line, and
the gas inlet and outlet disposed between the end portions of the light source support includes a slit between adjacent light source support pieces.

4. The LED lamp according to claim 1 or 2,
wherein the light source support is a rod-shaped body extending along the lamp axial line,
the cooling gas flow channel is formed in a through hole formed along the lamp axial line in the light source support, and
the gas inlet and outlet between the end portions of the light source support is an opening leading from the side surface to the through hole of the light source support.

5. The LED lamp according to any one of claims 1 to 3,
wherein a mounting board on which the plurality of LEDs is mounted is fixed to the light source support.

6. The LED lamp according to any one of claims 1 to 3,
wherein a mounting board on which the plurality of LEDs is mounted is fixed to the light source support, and the mounting board is made of a metal core board.

7. The LED lamp according to any one of claims 1 to 3,
wherein the light source support includes a member having a good thermal conductivity containing at least one of aluminum, copper, and a heat conductive resin.

8. The LED lamp according to any one of claims 1 to 3,
wherein the light source support includes a plurality of light source support pieces disposed so as to surround the cooling gas flow channel,
the plurality of light source support pieces is disposed so as to form a n-gon (n = 3 or more) as viewed in cross section perpendicular to the lamp axial line, and
the gas inlet and outlet disposed between the end portions of the light source support includes an opening slit or a mesh hole leading from a surface to the cooling gas flow channel of the light source support.

9. The LED lamp according to any one of claims 1 to 3,
wherein the light source support has shapes expanded at both the end portions, and a cross-sectional area of the cooling gas flow channel is relatively narrower at a central portion as compared to both the end portions.

10. The LED lamp according to any one of claims 1 to 3,

wherein the light source support pieces have a thickness of a central portion formed thicker as compared to both the end portions, and a cross-sectional area of the cooling gas flow channel is relatively narrower at a central portion as compared to both the end portions.

11. The LED lamp according to any one of claims 1 to 10, further comprising
a heat transfer device inside a top portion of the hermetically sealed glass container opposite to the base, the heat transfer device fixed to the light source support and made of a thermal conductivity resin.

12. The LED lamp according to claim 11, further comprising
an additional heat radiator in a top portion outside the hermetically sealed glass container, having a thermal conductivity relationship with the heat transfer device across the hermetically sealed glass container.

13. The LED lamp according to claim 4, further comprising
a gas flow acceleration fan in the vicinity of an upper end, a lower end, or the both of the light source support.

14. The LED lamp according to claims 1 or 2,
wherein a nitrogen gas is encapsulated in addition to the low molecular weight gas inside the hermetically sealed glass container.

Fig. 1A
(Prior Art)

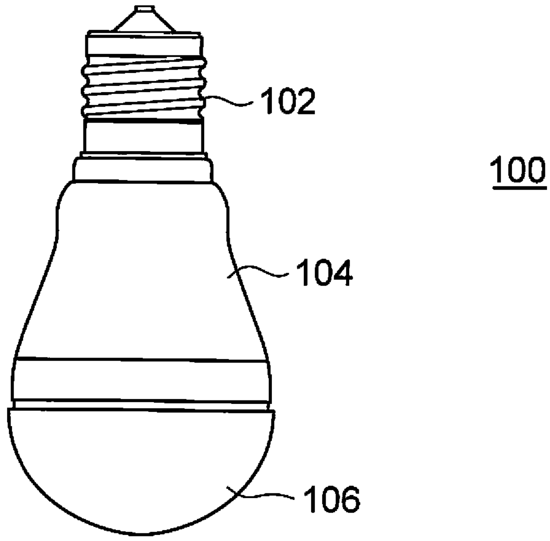


Fig. 1B
(Prior Art)

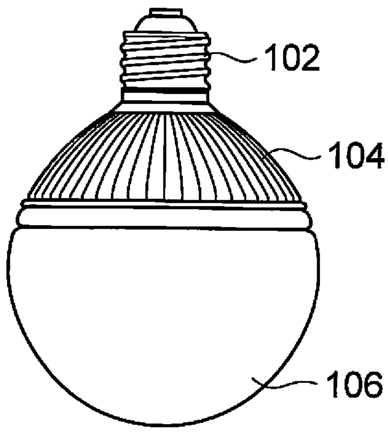


Fig. 1C
(Prior Art)

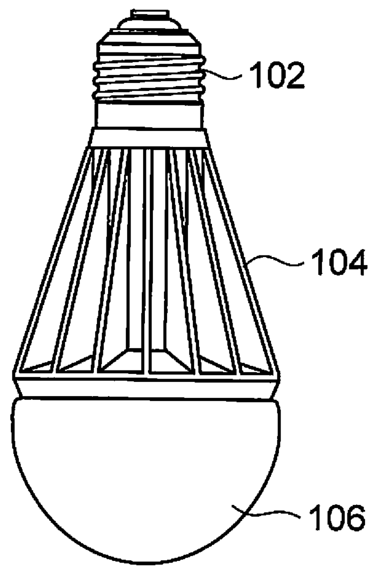


Fig. 2A

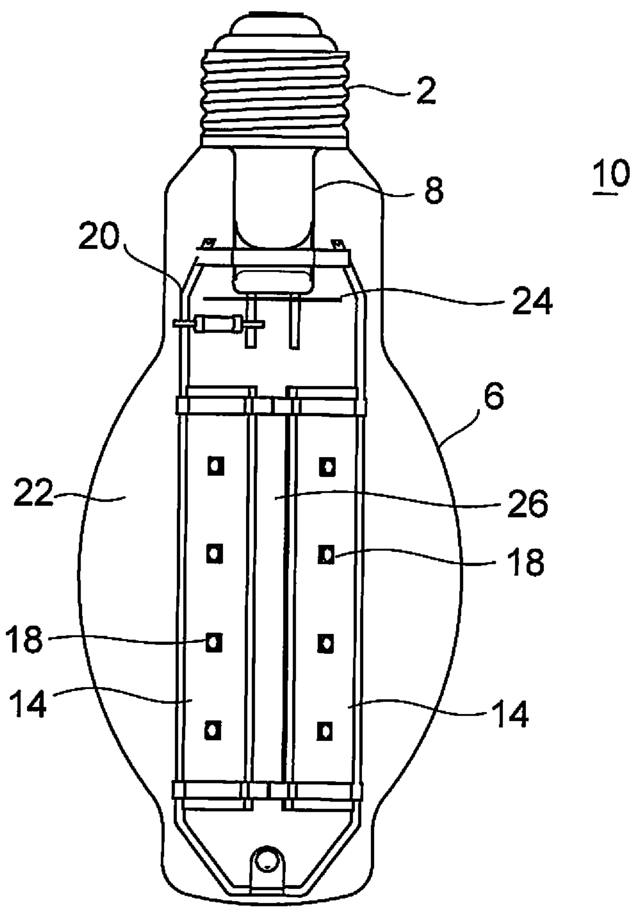


Fig. 2B

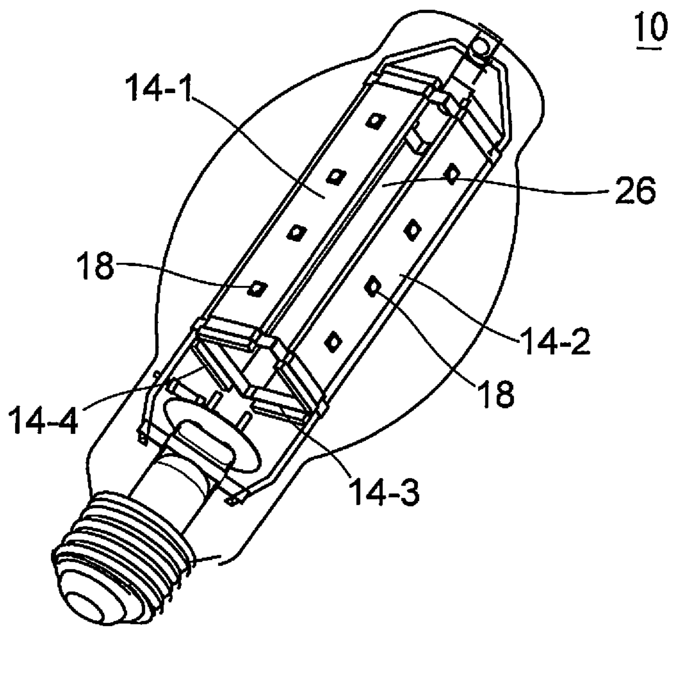


Fig.3A

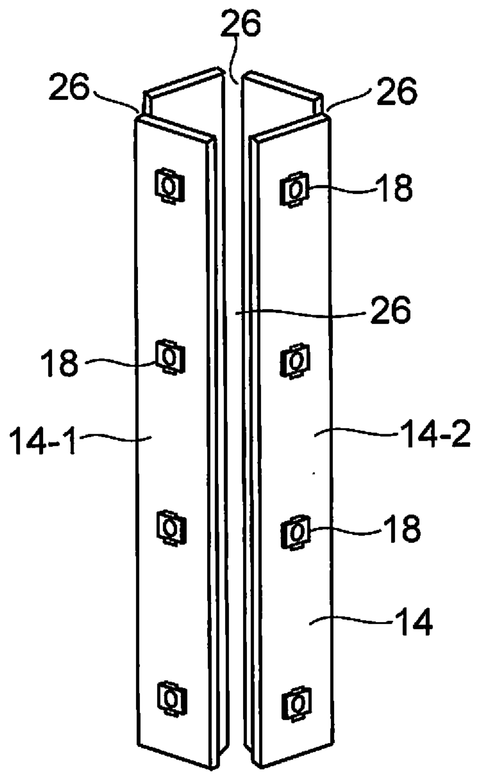


Fig.3B

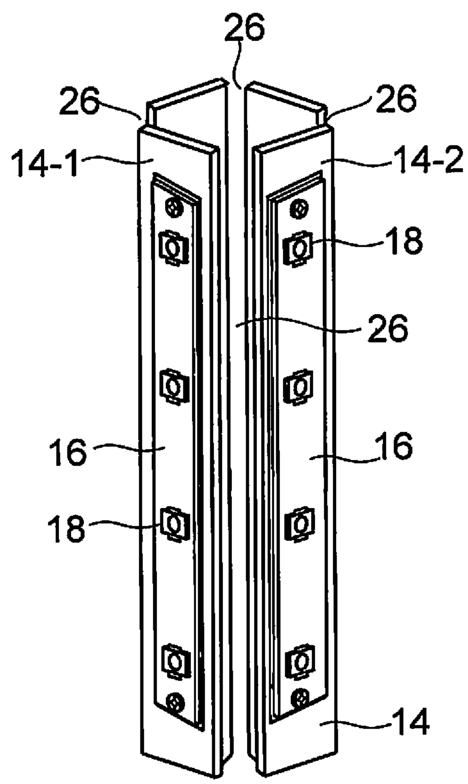


Fig. 4A

(Prior Art)

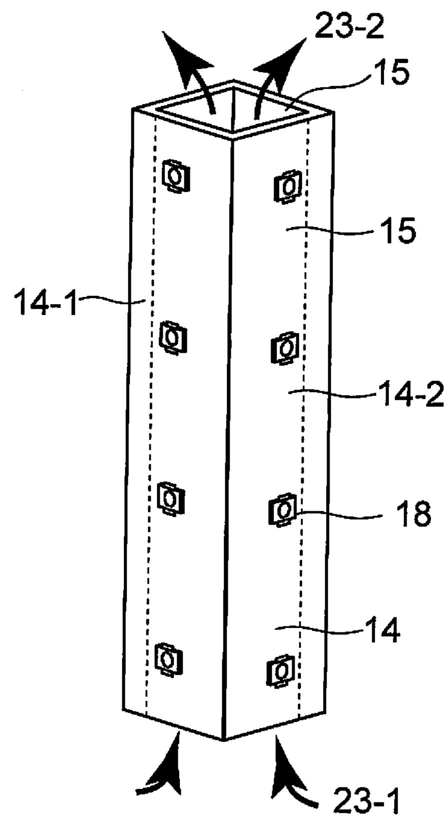


Fig. 4B

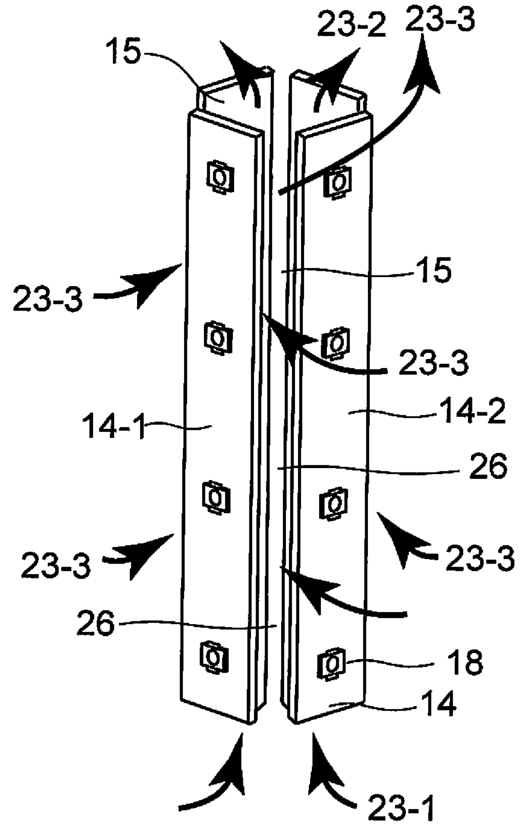
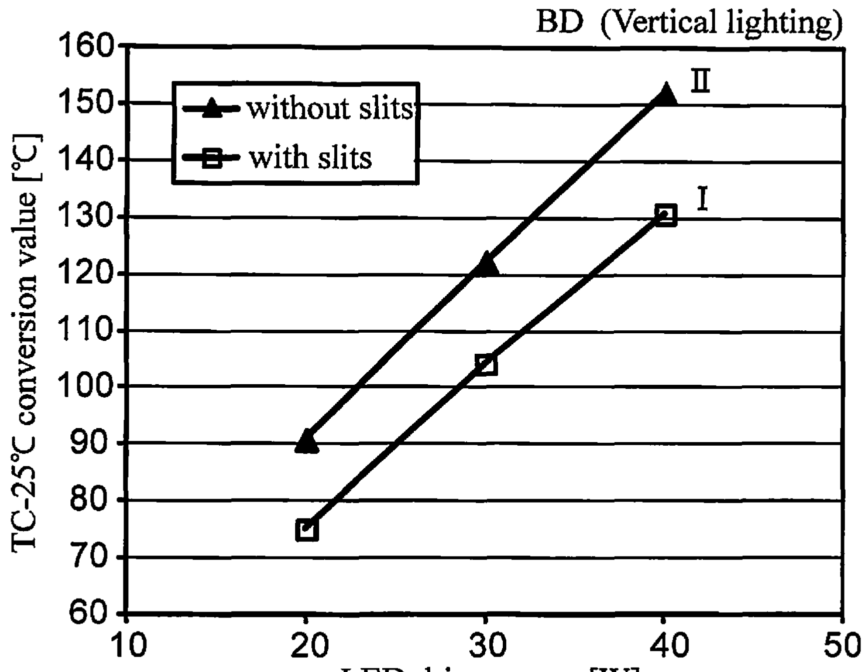
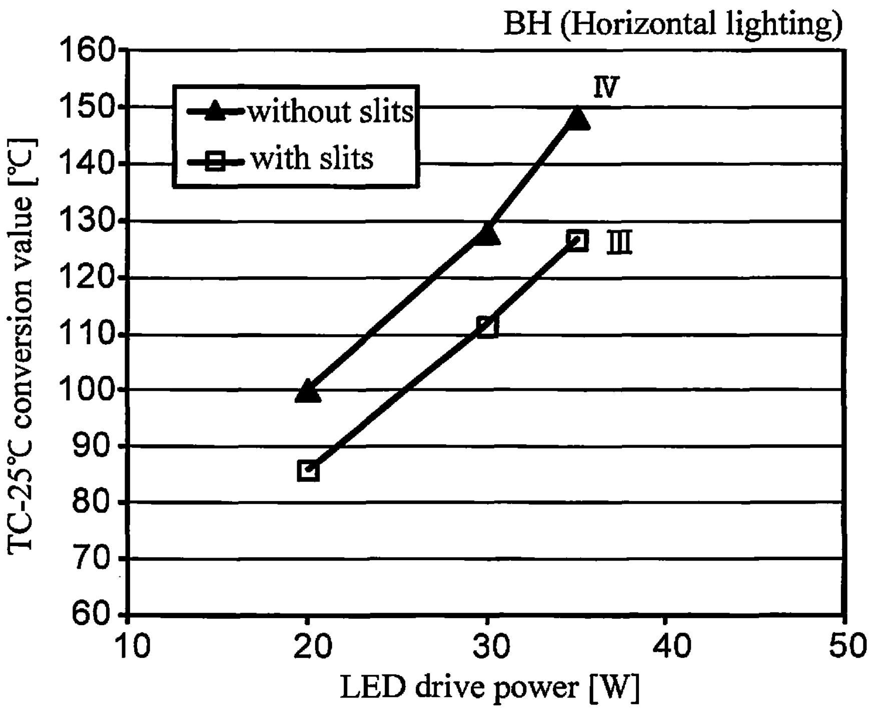


Fig. 5A



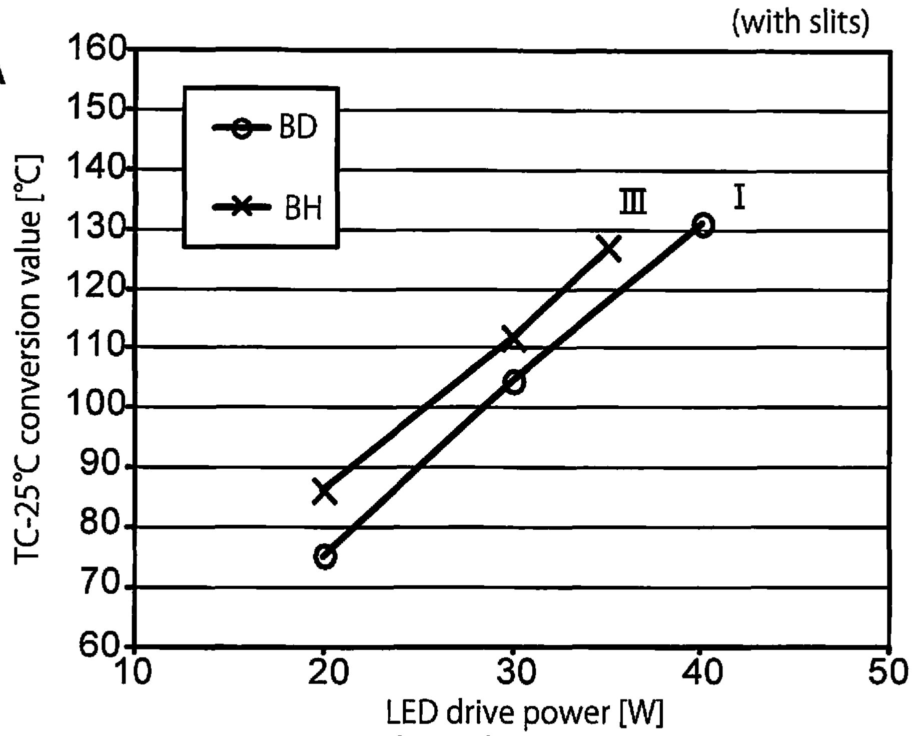
Comparison of LED element temparatures due to the presence or absence of slits

Fig. 5B



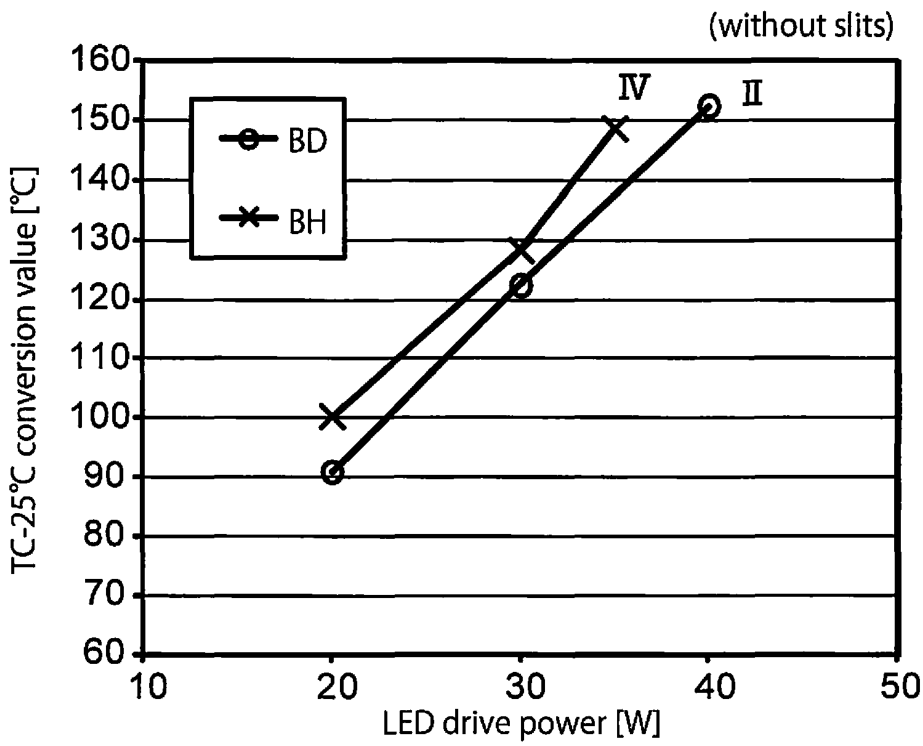
Comparison of LED element temparatures due to the presence or absence of slits

Fig. 6A



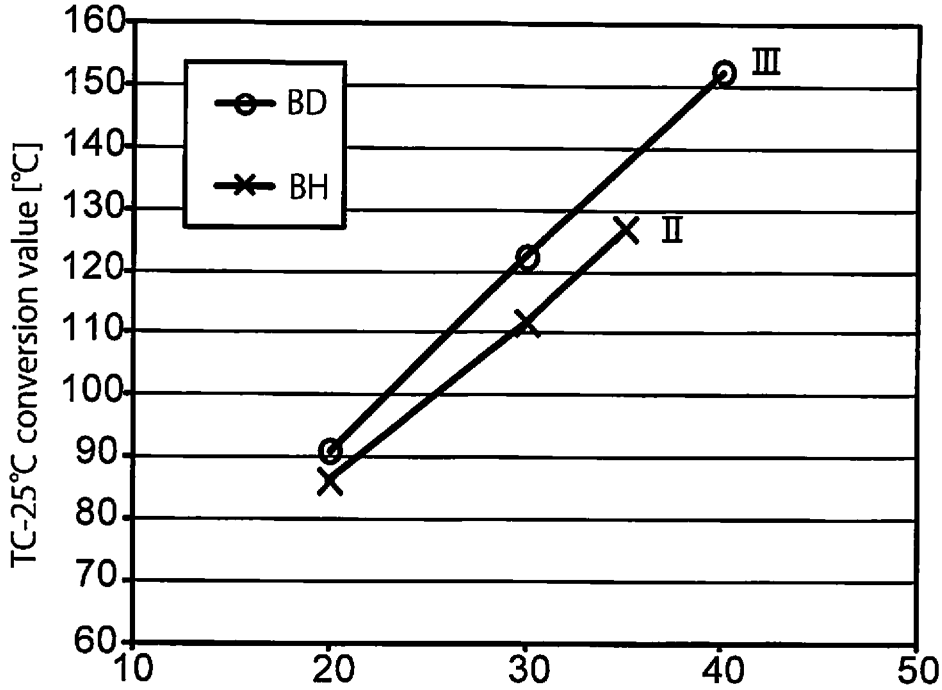
Comparison of LED element temparatures
due to the difference in the direction of lighting

Fig. 6B



Comparison of LED element temparatures
due to the difference in the direction of lighting

Fig. 7



Comparison of LED element temparatures
between III (BH with slits) and II (BD without slits)

Fig. 8A

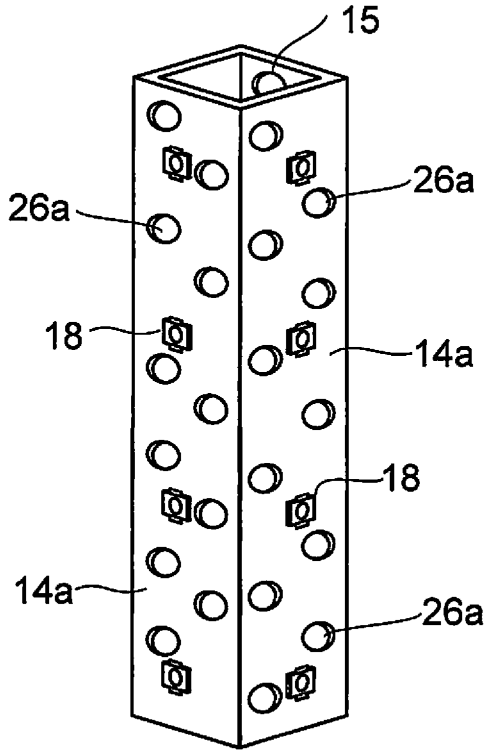


Fig. 8B

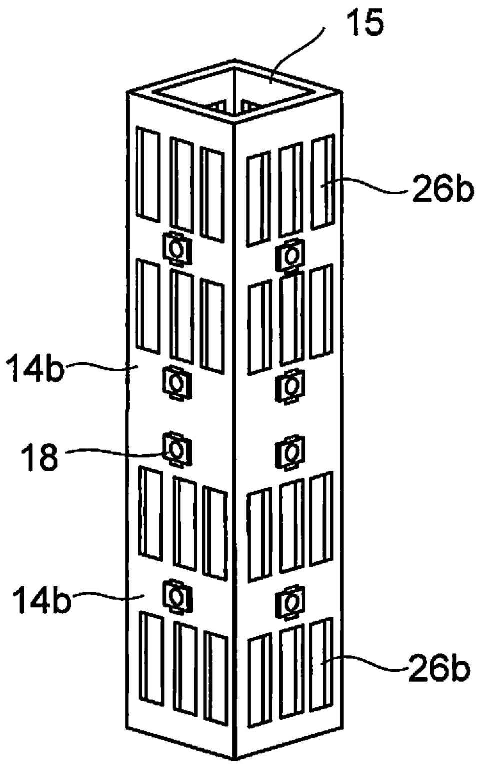


Fig. 9

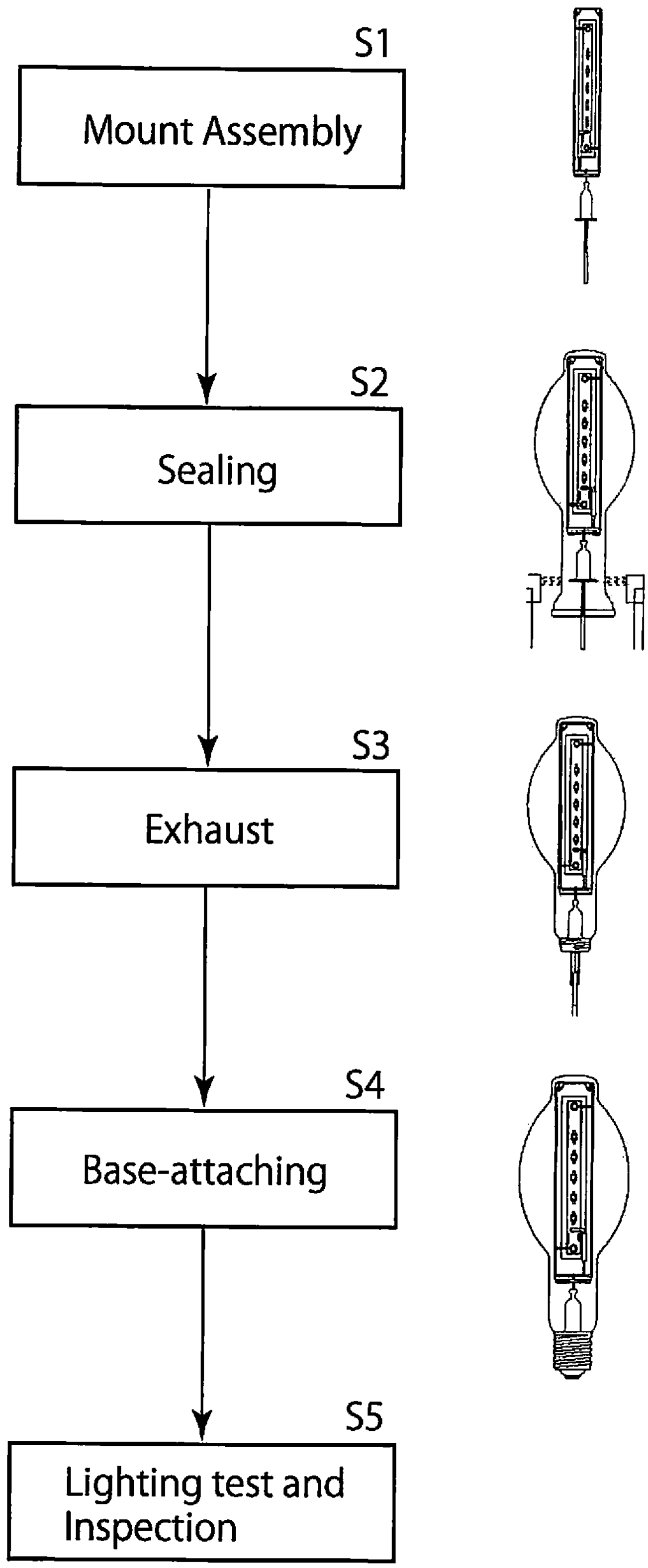

S1
Mount Assembly
S2
Sealing
S3
Exhaust
S4
Base-attaching
S5
Lighting test and Inspection

Fig. 10A

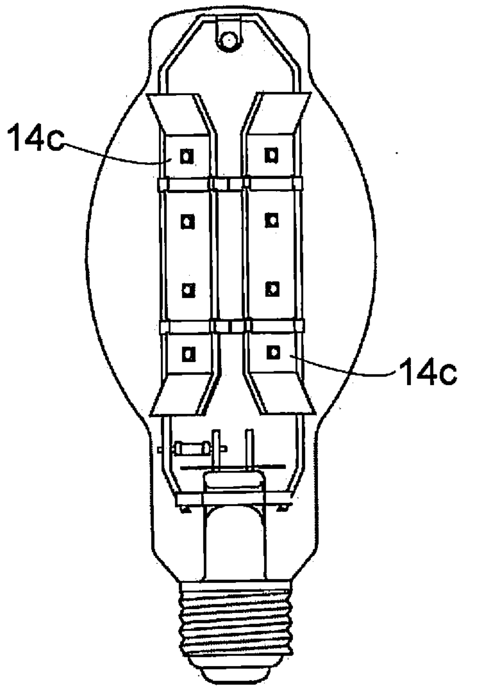


Fig. 10B

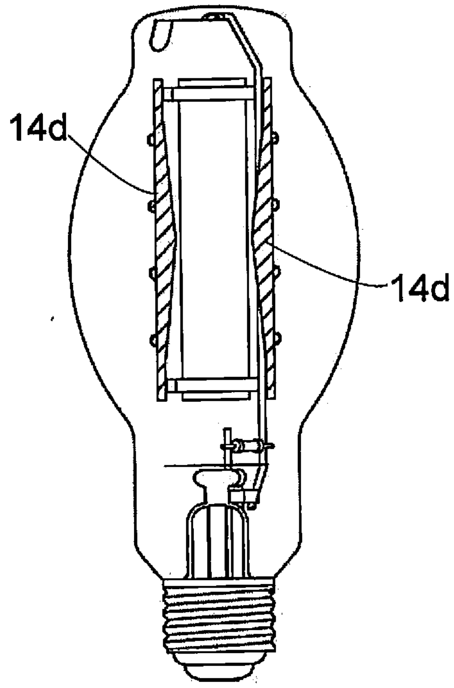


Fig. 11

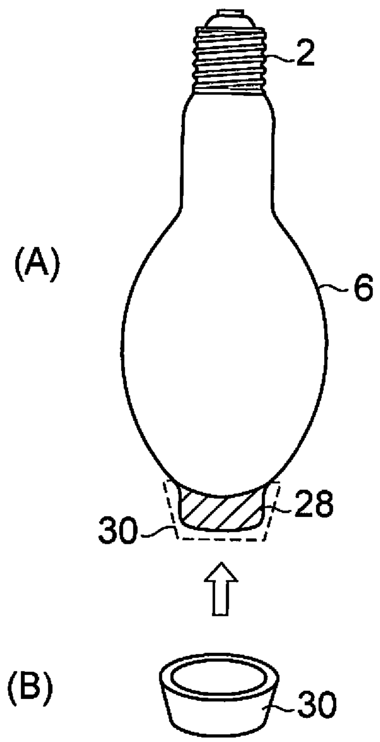
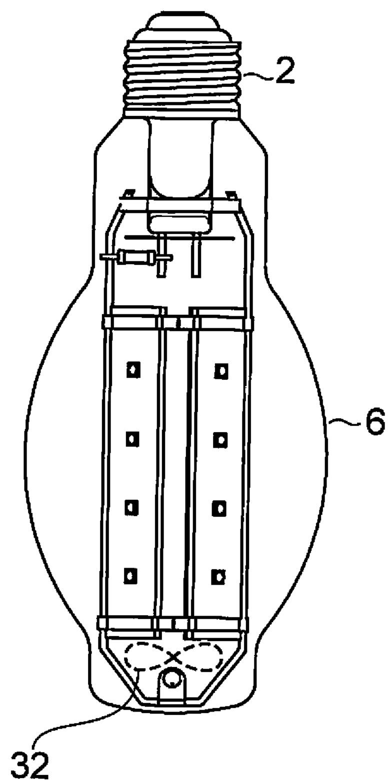


Fig. 12



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/077327

A. CLASSIFICATION OF SUBJECT MATTER
F21S2/00(2006.01)i, *F21V19/00*(2006.01)i, *F21V29/00*(2006.01)i, *F21V29/02*(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, F21V19/00, F21V29/00, F21V29/02, F21Y101/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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 2012-156036 A (Iwasaki Electric Co., Ltd.), 16 August 2012 (16.08.2012), paragraphs [0028] to [0057]; fig. 2 to 3, 5 (Family: none)	1-14
Y	WO 2011/118992 A2 (SOLARKOR CO., LTD.), 29 September 2011 (29.09.2011), paragraphs [0100] to [0110]; fig. 8 to 10 & JP 2013-524412 A & US 2013/0020462 A1 & KR 2011/0108269 A & CN 103052844 A & MX 2012011048 A	1-14

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 December, 2013 (03.12.13)	17 December, 2013 (17.12.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/077327

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-100734 A (LG Innotek Co., Ltd.), 19 May 2011 (19.05.2011), paragraphs [0096] to [0104]; fig. 46 & US 2011/0109217 A1 & EP 2320133 A2 & KR 2011/0050911 A & CN 102095101 A & TW 201118310 A	9-10
Y	WO 2011/098358 A1 (OSRAM GESELLSCHAFT MIT BESCHRANKTER HAFTUNG), 18 August 2011 (18.08.2011), page 5, line 6 to page 7, line 4; fig. 1 & US 2012/0306340 A1 & EP 2501986 A & WO 2011/098358 A1 & DE 102010001931 A1 & CN 102762912 A	14
A	JP 2012-501516 A (Solarkor Co., Ltd.), 19 January 2012 (19.01.2012), entire text; all drawings & US 2011/0156584 A1 & EP 2330345 A2 & WO 2010/024583 A2 & KR 10-0883346 B1 & KR 10-0883345 B1 & KR 10-0883344 B1 & CA 2734984 A1 & AU 2009284783 A & CN 102165251 A & MX 2011002018 A & TR 201101832 T & RU 2011110796 A	1-14
A	JP 3139851 U (Soyo GO), 06 March 2008 (06.03.2008), entire text; all drawings (Family: none)	1-14

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2010135181 A **[0005]**
- WO 2012095931 A1 **[0005]**
- JP 2012156036 A **[0005]**