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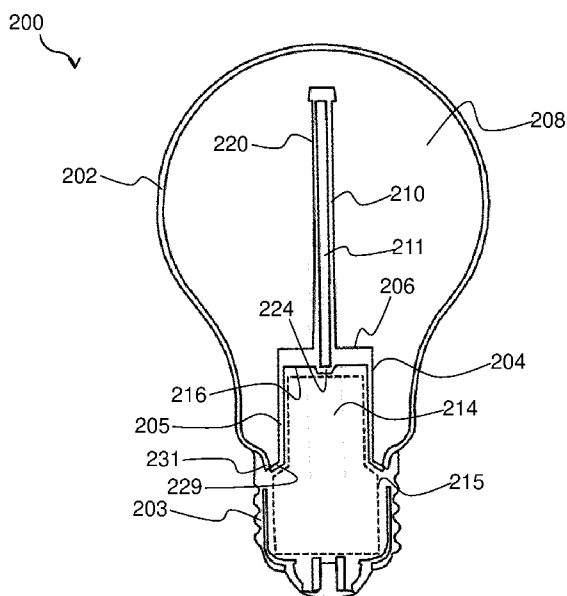


FIG. 2

(57) **Abstract:** Provided is a lighting device (200) comprising at least one solid state lighting source (212) and an envelope (202) which allows light from the solid state lighting source(s) to pass therethrough. The lighting device has a stem (204) to which the envelope is secured. A cavity (208) is delimited by the envelope and a first surface (206) of the stem. A first portion (210) of a shaft (220) extends from the first surface into the cavity along a longitudinal axis. The first portion supports the solid state lighting source(s). A recess (214) is provided in the stem, which recess is suitable for receiving at least part of a driver for controlling the solid state lighting source(s). The recess is at least partly delimited by a second surface (216). A protrusion (224) optionally protrudes from the second surface along the longitudinal axis. The recess has a minimum width perpendicular to the longitudinal axis of at least about 6 mm, such as at least about 9 mm. This minimum width may enable an apparatus to be inserted into the recess to remove a portion of a shaft extending in the recess from the stem along the longitudinal axis. In this way, the recess may be advantageously elongated along the longitudinal axis. A length of the recess along the longitudinal axis from the second surface when the protrusion is not present, or from an extremity of the protrusion when present, to a position aligned with an outermost periphery of the stem is greater than 8 mm. Further provided is such an apparatus for inserting into the recess, and a method of manufacturing the lighting device.

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LIGHTING DEVICE AND METHOD FOR MANUFACTURING THE SAME

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FIELD OF THE INVENTION

The present disclosure relates to a lighting device, in particular a LED filament bulb. The disclosure further relates to methods and apparatuses for manufacturing the lighting device.

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BACKGROUND OF THE INVENTION

LED filament bulbs are growing in popularity due to their premium appearance, longevity, and energy saving characteristics. As the demand increases, so does the desire to integrate more advanced functionality into such lighting devices.

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FIG. 1 schematically depicts an example of such a prior art lighting device 100. The lighting device 100 comprises an envelope 102 and a cap 103 for mounting the lighting device 100 onto a suitable standard fitting. The envelope 102 is secured to a stem 104, with a cavity 108 being delimited by the envelope 102 and a first surface 106 of the stem 104. As shown in FIG. 1, the stem 104 comprises a stem body 105 which protrudes into the envelope 102.

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An elongate support member 110 extends from the first surface 106 into the cavity 108. The elongate support member 110 supports the LED filament(s) (not visible in FIG. 1) which emits or emit light towards and through the envelope 102. The shaft 120 comprising the elongate support member 110 further comprises a second portion 122 which extends from a second surface 116 in a recess 114 provided in the stem 104. The shaft 120 may comprise a hollow tube having one or more hollow portions 111 therein, which together with a hole 101, may provide a fluid connection into the cavity 108 for gas filling/evacuation of the cavity 108 during manufacturing of the lighting device 100.

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As shown in FIG. 1, the second portion 122 occupies the recess 114. Thus, it tends to be only the interior of the cap 103 which provides space 115 for the driver circuitry (not visible) for controlling the luminous output of the LED filament(s), and thus the lighting effect provided by the lighting device 100 as a whole.

Such spatial constraints may hamper efforts to introduce further functionality to such lighting devices 100. This is because insufficient space within the lighting device 100 may preclude incorporation of more elaborate driver/control circuitry. Moreover, positioning the

driver further from the elongate support member 110, such as in the cap 103 as shown in FIG. 1, may disadvantageously require relatively long electrical connections between the driver and the LED filament(s), which may compromise the robustness and reliability of the lighting device 100.

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SUMMARY OF THE INVENTION

The invention is defined by the claims.

According to an aspect there is provided a lighting device comprising: an envelope which allows light to pass therethrough; a stem to which the envelope is secured, the stem having a first surface, wherein a cavity is delimited by the envelope and the first surface; a first portion extending from the first surface into the cavity, the first portion extending along a longitudinal axis; at least one solid state lighting source supported by the first portion, each of the at least one solid state lighting source being arranged to emit light towards and through the envelope; and a recess in the stem for receiving at least part of a driver for controlling the at least one solid state lighting source, the recess being at least partly delimited by a second surface, wherein the recess has a minimum width perpendicular to the longitudinal axis of at least about 6 mm, wherein a protrusion optionally protrudes from the second surface along the longitudinal axis, and wherein a length of the recess along the longitudinal axis from the second surface when the protrusion is not present, or from an extremity of the protrusion when present, to a position aligned with an outermost periphery of the stem is greater than 8 mm, wherein at least part of the stem is coated with a reflective material or the at least part of the driver is covered with a reflective sleeve arranged to reflect light towards the stem.

During manufacturing of the lighting device, the envelope and a stem assembly comprising the stem and a shaft may be arranged such that the cavity is defined by the first surface of the stem and the envelope. Both the envelope and the stem assembly are made of glass. This means that the envelope and the stem are both formed of an optically transmissive material. The stem and the envelope are fusion welded to each other to seal the cavity from environment. This arranging may result in the stem partitioning the cavity and the recess. Outermost periphery of the stem is the joint between the envelope and stem. A first portion of the shaft extends from the first surface into the cavity, which first portion defines the elongate support member.

In some examples, this arranging of the envelope and the stem assembly may be facilitated by the shaft further comprising a second portion which extends in the recess from a second surface of the stem. The second portion may, for instance, aid alignment of the envelope

and the stem assembly, and may also provide a convenient part of the stem assembly which can be gripped during arrangement of the envelope and the stem assembly. At least part of the second portion may be subsequently removed, for example by cutting off part of or all of the second portion, to provide more space in the recess.

5 By ensuring that the recess has a minimum width, for example minimum diameter, perpendicular to the longitudinal axis of at least about 6 mm, such as at least about 9 mm, more of the second portion may be removed from the shaft because the recess may be wide enough for a suitable apparatus to be protruded into the recess and used to remove the second portion, or part of the second portion, as close as possible to the second surface. More space may
10 therefore be provided in the recess along the longitudinal axis, for instance for the driver which controls the at least one solid state lighting source supported by the elongate support member. Moreover, this greater space in the recess may enable electrical connections between the driver and the solid state lighting source(s) to be advantageously shortened. Thus, counterintuitively, the key to maximizing the space in the recess along the longitudinal axis, thereby to attain such
15 benefits, is providing a recess which is wide enough in directions perpendicular to the longitudinal axis.

In other examples, the arranging of the envelope and the stem assembly may not require the shaft to have a second portion, in which case removal of the second portion is not required in order to provide more space in the recess along the longitudinal axis. Because no
20 part of any such second portion is present in the recess, no removing step, for example using the abovementioned apparatus, is required. This may mean that the minimum width of the recess can be relatively small, for example about 6 mm. Thus, in spite of the minimum width of the recess being relatively small, the absence of any protrusion protruding within the recess from the second surface along the longitudinal axis may assist the recess to have sufficient
25 space along the longitudinal axis which can be used, for example, to accommodate the driver.

The recess may have a maximum width, for example maximum diameter, perpendicular to the longitudinal axis of about 25 mm. By the width of the recess being less than or equal to about 25 mm, the compatibility of the stem with an adjoining cap, such as a screw cap or bayonet cap, for mounting the lighting device in a standard fitting, such as a screw
30 or bayonet fitting, may be facilitated. A relatively wide recess, for example a recess having a relatively large minimum width, may not require a specially designed apparatus to remove the second portion of the shaft, when such a second portion is used during arranging of the stem assembly and the envelope. Moreover, a relatively large lateral space may be available to, for instance, accommodate the driver.

The recess may be at least partly delimited by the second surface, as previously described. In some examples, a protrusion protrudes from the second surface along the longitudinal axis. The protrusion may, in some examples, be left following removal of part of the second portion of the shaft. In other examples, no such protrusion may be present due to
5 no second portion of the shaft being used during arranging of the envelope and the stem assembly.

A length of the recess along the longitudinal axis from the second surface when the protrusion is not present, or from an extremity of the protrusion when such a protrusion is present, to a position aligned with an outermost periphery of the stem is greater than 8 mm.

10 Removal of the second portion of the shaft as close as possible to the second surface may effectively permit lengthening of the recess, such that its length is greater than 8 mm. This is because more of, or in some examples the entirety of, the second portion may be removed by the apparatus when it is received in the recess. This may advantageously provide more space in the recess, for instance for the driver which controls the at least one solid state lighting
15 source.

The first portion may comprise a hollow tube, or may be in the form of a solid rod. When the first portion comprises the hollow tube, the hollow portion or portions within the first portion may extend from the stem and provide a fluid connection between the cavity and the recess during manufacturing of the lighting device. In such an example, the first portion
20 may serve several purposes: supporting the at least one solid state lighting source, and facilitating gas filling/evacuation of the cavity via the hollow portion(s) during the manufacturing.

The solid shaft may, on the other hand, have no hollow portion extending within the shaft from the stem. Thus, removal of the second portion need not involve forming a seal to
25 prevent fluid communication between the recess and the cavity via, in other words through, the shaft. Obviation of the requirement to form such a seal, which would otherwise be necessary when, for instance, the first portion is in the form of a hollow tube, means that the second portion can be removed at a position closer to the second surface. More space may therefore be provided in the recess, for instance for the driver which controls the at least one solid state
30 lighting source supported by the first portion.

In other examples, the second portion, when such a second portion is used, may be hollow, but the hollow portion(s) of the second portion may not be in fluid communication with the cavity. For example, a blind in the shaft may prevent such fluid communication

between the recess and the cavity. In this case, no seal is required at or proximal to the second surface.

The lighting device may comprise the driver, and at least part of the driver may be received in the recess. The greater space provided in the recess may, for instance, permit more of the driver to be accommodated in the recess. Alternatively or additionally, the driver may include more elaborate circuitry for controlling the at least one solid state lighting source, since the additional space required by such more elaborate circuitry may be accordingly provided in the recess. The overall effect may be to improve the lighting and/or lighting control delivered by the lighting device.

The driver may comprise components such as capacitors, resistors, a printed circuit board (PCB), etc., whose exterior surfaces have different colors. The colors of the external, e.g. painted, surfaces of such components necessarily mean that some visible wavelengths of light are absorbed, and the remaining visible wavelengths corresponding to the perceived color of the external surface are reflected. Visible wavelengths of light are in the range of 380 to 700 nm.

In one set of examples, one or more surfaces of the stem, and preferably the second surface delimiting the recess, is or are coated with a reflective material. In this manner, the absorption of light by colored components of the driver can be minimized or prevented.

The term “reflective material” in this context is intended to mean a reflective material which does not absorb or only negligibly absorbs visible wavelengths of light, e.g., reflects more than 80%, preferably 95% or more preferably 98%, of incident light.

In an alternative set of examples, the driver is covered with a reflective sleeve arranged to reflect light towards the optically transmissive stem. This also assists to minimize or prevent the above-described light absorption by the colored external surfaces of the components of the driver.

The term “reflective sleeve” in this context is intended to mean a reflective sleeve whose exterior does not absorb or only negligibly absorbs visible wavelengths of light, e.g., reflects more than 80%, preferably 95% or more preferably 98%, of incident light.

Light from the at least one solid state lighting source incident on the reflective surface of the coating of reflective material or on the reflective sleeve may, rather than being absorbed by any colored surfaces of the components of the driver, be reflected from or through the stem, and ultimately through the envelope of outside of the lighting device. Thus, the overall optical efficiency of the lighting device may be improved. In particular, such modification may improve the overall optical efficiency of the lighting device by around 1%.

According to another aspect there is provided a method for manufacturing a lighting device, the method comprising: providing an envelope which allows light to pass therethrough; providing a stem assembly comprising a stem, and a shaft extending along a longitudinal axis, wherein a first portion of the shaft extends from a first surface of the stem, a second surface of the stem at least partly delimiting a recess in the stem, wherein the recess has a minimum width perpendicular to the longitudinal axis of at least about 6 mm; applying a reflective material on at least part of the stem or covering at least part of a driver for controlling at least one solid state lighting source with a reflective sleeve; supporting the at least one solid state lighting source on the first portion; and arranging the envelope and the stem assembly such that the first portion extends from the first surface into a cavity delimited by the envelope and the first surface.

In some examples, a second portion of the shaft may extend in the recess from the second surface. In such examples, the method may further comprise, subsequent to the arranging of the envelope and the stem assembly, removing at least part of the second portion.

The second portion may, for instance, aid alignment of the envelope and the stem assembly, and may also provide a convenient part of the stem assembly which can be gripped during arrangement of the envelope and the stem assembly. At least part of the second portion of the shaft may be subsequently removed, for example by cutting off part of or all of the second portion, to provide more space in the recess. By the recess having a minimum width perpendicular to the longitudinal axis of at least about 6 mm, such as at least about 9 mm, more of the second portion may be removed from the shaft, as previously described.

In other non-limiting examples, arranging of the envelope and the stem assembly may not require such a second portion; alignment and gripping of the stem being achieved in an alternative manner, which may mean that the minimum width of the recess can be relatively small, for example about 6 mm.

When the shaft includes the second portion, the removing may comprise: receiving an apparatus for removing the at least part of the second portion in the recess; and using the apparatus to remove the at least part of the second portion while the apparatus is received in the recess.

A length of the recess along the longitudinal axis from the second surface when the second portion has been removed, or from an extremity of a protrusion defining a remainder of the second portion left following the removing, to a position aligned with an outermost periphery of the stem may be greater than 8 mm. The outermost periphery of the stem is normally included in, or defined by, the connecting region between the stem and the envelope.

In the manufacturing process of a lamp bulb, the glass envelope is fusion welding with the glass stem at this connecting region.

At least the second portion of the shaft may be formed from, for example, a glass rod or a glass tube. In other words, the first portion and/or the second portion of the shaft may be formed from a glass tube or a glass rod. In such examples, the removing may comprise flame cutting or using a glass knife to cut the glass rod or the glass tube.

When the first portion is formed of a glass tube or a glass rod, the first portion, in other words the elongate support member, may have suitable rigidity for supporting the at least one solid state lighting source.

A glass knife may, for example, be used to remove the second portion when the second portion is formed from a glass rod (or when the second portion is formed from a glass tube but the hollow portion of the glass tube is not in fluid communication with the cavity). In this case, no seal is required at or proximal to the second surface.

The method may further comprise receiving at least part of the driver in the recess. The receiving of the driver within the recess may be implemented subsequently to the removing of the second portion.

The method may further comprise trapping a gas in the cavity. The gas may be trapped in the cavity by, for example, the envelope being sealingly secured to the stem. Moreover, the gas may be prevented from leaking from the cavity into the recess through the shaft. When, for example, the second portion is in the form of a hollow tube, the removing of the hollow tube may be implemented in such a way as to limit or prevent fluid communication between the recess and the cavity via the shaft. This may involve forming a seal at or proximal to the second surface.

Alternatively, when the second portion is in the form of a solid rod, or a hollow tube whose hollow portion(s) does or do not fluidly communicate with the cavity, the second portion may be removed in any suitable manner. This is because no seal is required to be formed during removal, for example cutting, of such a second portion.

The gas trapped in the cavity may comprise at least one of helium, neon, argon, krypton, and xenon. Noble gases, and helium in particular, may effectively transfer heat from the at least one solid state lighting source to the envelope. The enhanced heat dissipation from trapping a gas comprising such a noble gas or gases in the cavity may assist to increase the longevity of the at least one solid state lighting source.

The trapping may comprise: filling the cavity with the gas via an opening in the envelope; and closing the opening to trap the gas in the cavity.

A glass tube may extend from the opening and provide a fluid connection to a source of the gas, and wherein the closing comprises sealing the glass tube at or proximal to the opening. The opening and the glass tube may facilitate manufacturing of a lighting device having a gas trapped in the cavity, but without the stem assembly being required to include a hollow shaft for gas filling and/or evacuating the cavity. The opening may, for instance, oppose the stem across the cavity following the arranging of the envelope and the stem assembly.

The sealing may, for example, comprise forming a further protrusion on the envelope. In some examples, the method further comprises removing the further protrusion. Removal of the further protrusion, such as a glass protrusion when the envelope is a glass envelope, may assist to maintain relatively uniform optical transmissivity across the envelope, since the further protrusion may otherwise attenuate and/or scatter light to a greater degree than other portions of the envelope. Removal of the further protrusion may also improve the aesthetic appearance of the lighting device. In other examples, the further protrusion may remain on the envelope following manufacturing of the lighting device.

According to a further aspect there is provided an apparatus for flame cutting a shaft of a stem assembly suitable for securing to an envelope, the stem assembly further comprising a stem having a recess which is at least partly delimited by a surface from which the shaft axially extends, the apparatus comprising: a housing for inserting axially into the recess, the housing delimiting an aperture for passing the shaft therethrough; a flame outlet arranged to direct a flame radially from the housing into the aperture, the flame being thereby directed towards the shaft when the shaft is passed through the aperture; and a conduit for supplying a combustible gas to the flame outlet.

The housing may prevent direct exposure of the stem to the flame being directed from the flame outlet. Thus, the housing may assist to prevent exposure of the surface, in other words the above-described second surface of the stem, to the flame.

By the housing being insertable into the recess of the stem, the shaft may be removed from a position which is relatively close to the surface of the recess. In other words, the apparatus may assist in removing at least part of the above-described second portion as close as possible to the (second) surface of the stem from which it extends. This may assist to provide greater space inside the recess, for example for accommodating the driver.

The width of the housing in radial directions may, for example, be in the range of 6 mm to 25 mm in order for the housing to be insertable into the recess.

It is nevertheless reiterated that in other examples in which no second portion is employed, the apparatus is not required, and the minimum width of the recess can be made smaller.

An axial distance from a distal external surface of the housing to a midpoint of the flame outlet may, for example, be less than 10 mm, such as less than 5 mm, for example, less than 2 mm. The distal external surface of the housing may approach, and in some cases contact, the (second) surface. Accordingly, such a maximum axial distance may assist to ensure that the axial protrusion of a remainder of the (second portion of the) shaft being left following the removing into the recess is minimized.

The flame outlet may, for example, extend around at least part of a perimeter of the aperture. By the flame outlet extending around at least part of the perimeter of the aperture, the shaft may be evenly heated around its circumference, which may facilitate removal of the second portion.

The apparatus may be suitable for removing solid and hollow glass shafts. When the shaft comprises a hollow glass tube, the portion of glass aligning with the flame outlet may melt to seal the shaft at the same time as or relatively soon after the removing.

The apparatus may further comprise a cooling system for cooling the housing while the combustible gas is being burned at the flame outlet. The cooling system may further assist to provide greater space inside the recess because the housing of the apparatus may be brought closer to the second surface than, for example, when no cooling system is included in the apparatus. This may be due to the cooling system assisting to minimize the risk of the housing transferring heat to, and thus damaging, other components of the lighting device while the second portion is being removed.

In a non-limiting example, the cooling system comprises: an inlet; a channel within the housing arranged to receive, from the inlet, fluid for cooling the housing, the fluid being heated in the channel by heat generated from burning of the combustible gas at the flame outlet; and an outlet for permitting the heated fluid to exit the channel. Such a heat exchange system may provide a convenient way of cooling the housing, and particularly its external surfaces facing the recess of the stem, so that the apparatus can be brought closer to the (second) surface from which the (second portion of) the shaft extends. The fluid may, for example, comprise or consist of water.

More generally, the lighting device as described above may be obtained via the method and/or using the apparatus as described above. Accordingly, examples described in relation to the method and/or the apparatus may be applicable to the lighting device, and

examples described in relation to the lighting device may be applicable to the method and/or the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

FIG. 1 provides a cross-sectional view of a prior art lighting device;

FIG. 2 provides a cross-sectional view of a lighting device according to an example;

10 FIG. 3 provides a cross-sectional view of a lighting device according to another example;

FIG. 4 provides a cross-sectional view of a stem assembly according to an example;

FIG. 5 provides a cross-sectional view of a stem assembly according to another example;

15 FIG. 6 provides a cross-sectional view of an envelope and a stem assembly according to an example;

FIG. 7 provides a cross-sectional view of an envelope and a stem assembly according to another example;

FIG. 8 provides a cross-sectional view of part of a lighting device according to a further example;

20 FIG. 9A provides a perspective view of an apparatus according to an example;

FIG. 9B provides an enlarged cross-sectional view of the apparatus shown in FIG. 9A;

FIG. 10 schematically depicts an exemplary use of the apparatus shown in FIGs. 9A and 9B in the manufacture of a lighting device;

25 FIG. 11 schematically depicts a further exemplary use of the apparatus shown in FIGs. 9A and 9B in the manufacture of exemplary lighting devices;

FIG. 12A provides a perspective view of an apparatus according to another example;

FIG. 12B provides a cutaway view of the apparatus shown in FIG. 12A;

30 FIG. 13 schematically depicts a step in manufacturing of a lighting device, for comparison with FIGs. 10 and 11; and

FIG. 14 provides a flowchart of a method according to an example.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention will be described with reference to the Figures.

It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the apparatus, systems and methods, are intended for purposes of illustration only and are not intended to limit the scope of the invention. These and other features, aspects, and advantages of the apparatus, systems and methods of the present invention will become better understood from the following description, appended claims, and accompanying drawings. It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

Provided is a lighting device comprising at least one solid state lighting source and an envelope which allows light from the solid state lighting source(s) to pass therethrough. The lighting device has a stem to which the envelope is secured. A cavity is delimited by the envelope and a first surface of the stem. An elongate support member extends from the first surface into the cavity along a longitudinal axis. The elongate support member supports the solid state lighting source(s). A recess is provided in the stem, which recess is suitable for receiving at least part of a driver for controlling the solid state lighting source(s). The recess is at least partly delimited by a second surface. A protrusion optionally protrudes from the second surface along the longitudinal axis. The recess has a minimum width perpendicular to the longitudinal axis of at least about 6 mm, such as at least about 9 mm. This minimum width may enable an apparatus to be inserted into the recess to remove a portion of a shaft extending in the recess from the stem along the longitudinal axis. In this way, the recess may be advantageously elongated along the longitudinal axis. A length of the recess along the longitudinal axis from the second surface when the protrusion is not present, or from an extremity of the protrusion when present, to a position aligned with a lowermost periphery of the stem is greater than 8 mm. Further provided is such an apparatus for inserting into the recess, and a method of manufacturing the lighting device.

FIG. 2 provides a cross-sectional view of a lighting device 200 according to an example. The lighting device 200 comprises an envelope 202 whose optical transmissivity permits light to exit the lighting device 200. The lighting device 200 comprises at least one solid state lighting source (not visible in FIG. 2) which emits or emit light towards and through the envelope 202.

The lighting device 200 in this example further comprises a cap 203 for mounting the lighting device 200 in or on a suitable fitting (not visible in FIG. 2). The fitting may comprise contacts which provide an electrical connection with corresponding contacts on the cap 203 when the lighting device 200 is mounted in or on the fitting. In this way, power may

be supplied to the lighting device 200 via the fitting. The cap 203 of the non-limiting example shown in FIG. 2 comprises or consists of a threaded cap 203 for screwing into a complementary threaded fixture. In other examples, the cap 203 may comprise or consist of a bayonet cap 203 for fitting into a suitable bayonet mount. Other suitable cap 203 and fitting designs will be immediately apparent to the skilled person, and will not be further described herein for the sake of brevity only.

The cap 203 may be formed of any suitable material, such as a metal or metal alloy. The cap 203 may be secured to the envelope 202 in any suitable manner, such as with a suitable adhesive.

The envelope 202 may be formed from any suitable optically transmissive glass, such as fused silica. Since the envelope 202 is formed from glass, the envelope 202 may be particularly suited for transferring heat away from at least one solid state lighting source (not visible in FIG. 2) which directs light towards and through the envelope 202. Heat may be transferred from the solid state lighting source(s) to the glass envelope 202, for example via a suitable thermally conductive gas, as will be explained in more detail herein below. The glass envelope 202 may then assist to dissipate the heat from the solid state lighting source(s) to the surroundings.

The combination of the envelope 202, the cap 203, and the solid state lighting source(s) being in the form LED filament(s) means that the lighting device 200 may be regarded as an LED filament bulb.

The envelope 202 may, for example, comprise a diffuser coating (not visible in the Figures), for instance comprising a powdered silica coating, in order that the lighting device 200 provides a relatively diffuse lighting effect. Such a diffuser coating may assist the lighting device 200 to, in spite of the inherent point source characteristics of the solid state lighting elements which may be included in the solid state lighting sources, e.g. included in the LED filament(s), provide a relatively uniform lighting effect across the surface of the envelope 202.

In other non-limiting examples, the envelope 202 may be clear, in other words non-frosted, which may assist to provide a more intense and/or sparkle-effect luminous output from the lighting device 200. In such examples, it may be possible to view the solid state lighting source(s) through the envelope 202, which has been found to add to the aesthetic appeal of the lighting device 200.

The envelope 202 may have any suitable shape or profile, for example Type A (arbitrary), Type B (bulged), Type BT (blown tubular), Type C (candle), Type E (ellipsoidal), Type F (flame), Type G (globe), Type P (pear), Type S (straight), Type T (tubular). The

selection of the envelope shape 202 may, in certain examples, have at least some influence on the dimensions of other components of the lighting device 200, such as the stem 204, as will be explained further herein below.

As shown in FIG. 2, the envelope 202 is secured to the stem 204, with a cavity 208 being delimited by the envelope 202 and a first surface 206 of the stem 204. As also shown in FIG. 2, the stem 204 comprises a stem body 205 which protrudes into the envelope 202. An outer surface of the stem body 205 thus defines the first surface 206 of the stem 204.

The stem 204 may be formed from any suitable material, in particular the stem 204 is formed from glass. A glass stem 204 may, for instance, be particularly suitable for securing to the glass envelope 202.

The envelope 202 may be sealingly secured to the stem 204 in order to assist with trapping of a gas within the cavity 208. In such an example, a seal or weld may be formed between an outermost portion 229 of the stem body 205 and a mouth portion 231 of the envelope 202. The seal or weld may provide a barrier which assists to prevent the trapped gas from leaking from the cavity 208.

The gas trapped in the cavity 208 may comprise, for example, at least one of helium, neon, argon, krypton, and xenon. Noble gases, and helium in particular, may effectively transfer heat from the solid state lighting source(s) to the envelope 202. The enhanced heat dissipation from trapping a gas comprising such a noble gas or gases in the cavity 208 may assist to increase the longevity of the solid state lighting source(s).

Whilst not visible in FIG. 2, electrical connections, for example wires, may extend through the stem body 205. In this way, the solid state lighting source(s) is or are connected with suitable control circuitry external to the cavity 208. Such electrical connections may, for instance be sealed in the stem body 205 in order to prevent gas leakage via such electrical connections. In a non-limiting example, the electrical connections may take the form of wires which are sealed around their circumference in a glass stem body 205.

An elongate support member 210 extends from the first surface 206 into the cavity 208. As shown in FIG. 2, the elongate support member 210 may extend into a central portion of the cavity 208. In combination with a rotationally symmetric envelope 202, the radial distance between the elongate support member 210 and the envelope 202 at any given point along its length may be constant or substantially constant around the perimeter, for example circumference, of the elongate support member 210 at that point.

The elongate support member 210 supports the solid state lighting source(s) (not visible in FIG. 2). The elongate support member 210 may be joined, for example welded or

fused, to the stem 204. The elongate support member 210 may be formed from, for instance, a suitable glass. In this respect, the elongate support member 210 may be formed from the same material as the stem 204 or from a different material. In a non-limiting example, both the stem 204 and the elongate support member 210 are formed from glass.

5 As shown in FIG. 2, the elongate support member 210 comprises a hollow tube. The hollow tube has one or more hollow portions 211 therein, which may assist to make the elongate support member 210 more lightweight.

 Moreover, in some examples, the hollow portion or portions 211 within the elongate support member 210 may extend from the stem body 205 and provide a fluid connection
10 between the cavity 208 and the recess 214 during manufacturing of the lighting device 200. In such examples, the elongate support member 210 may facilitate gas filling/evacuation of the cavity 208 during the manufacturing. The gas used to fill the cavity 208 may comprise, for example, one or more of the noble gases described above. Following such gas filling, the fluid connection may be removed with a seal included in a protrusion 224 which protrudes in a recess
15 214 of the stem 204, as will be described in more detail herein below.

 In other examples, the stem 204 and the elongate support member 210 extending therefrom may not provide any fluid connection with the cavity 208 during manufacturing of the lighting device 200. In such examples, the role of the elongate support member 210 may be confined to supporting the solid state lighting source(s). An alternative fluid connection for
20 gas filling/evacuation of the cavity 208 which is neither provided in the stem 204 nor in the elongate support member 210 may be used, and an example of this will be described in greater detail herein below with reference to FIG. 7.

 In the non-limiting example shown in FIG. 3, the elongate support member 210 is in the form of a solid shaft. The absence of any hollow portion 211 extending within the solid
25 shaft from the stem 204 may obviate the requirement to form the seal in the protrusion 224 described above in relation to FIG. 2. This may mean that any such protrusion 224 may be smaller than the scenario in which a seal is required. Alternatively, such a protrusion 224 may be absent from the recess 214. In both of these cases, more space may be provided in the recess 214, for instance for the driver (not visible in the Figures) which controls the solid state lighting
30 source(s).

 During manufacturing of the lighting device 200, the envelope 202 and a stem assembly 204, 220 comprising the stem 204 and a shaft 220 may be arranged such that the cavity 208 is defined by the first surface 206 of the stem 204 and the envelope 202. This arranging may result in the stem 204 partitioning the cavity 208 and the recess 214. A first

portion 210 of the shaft 220 extends from the first surface 206 into the cavity 208, which first portion defines the elongate support member 210.

In a first set of examples, this arranging of the envelope 202 and the stem assembly 204, 220 may be facilitated by the shaft 220 further comprising a second portion (not visible in FIGs. 2 and 3) which extends in the recess 214 from a second surface 216 of the stem 204. The second surface 216 is the inner surface of the stem delimiting the recess 214. The second surface 216 is opposite the first surface 206 facing the cavity 208. The second portion may, for instance, aid alignment of the envelope 202 and the stem assembly 204, 220, and may also provide a convenient part of the stem assembly 204, 220 which can be gripped during arrangement of the envelope 202 and the stem assembly 204, 220. At least part of the second portion may be subsequently removed, for example by cutting off part of or all of the second portion, to provide more space in the recess 214. In this way, the recess 214 in the stem 204 may, for example, be used to accommodate at least part of the driver for controlling the solid state lighting source(s). The dashed line 215 in FIGs. 2 and 3 represents the available space in the recess 214, as well as inside the cap 203, which may be used, for instance, to accommodate the driver. This contrasts with the prior art lighting device 100 shown in FIG. 1 in which part of the second portion 122 occupies the recess 114, such that the available space 115 for the driver is confined to the interior of the cap 103.

It is particularly desirable to maximize the space in the recess 214 along the longitudinal axis because components, such as the driver, can be accommodated in the recess 214 as close as possible to the elongate support member 210 and the solid state lighting source(s) mounted thereon. Relatively short connections may thus, for example, be made between the driver and the solid state lighting source(s).

FIGs. 4 and 5 provide a cross-sectional views of respective exemplary stem assemblies 204, 220. In the above-described first set of examples, the second portion of the shaft 220 may be removed by inserting a suitable apparatus into the recess 214 and removing, e.g. cutting off, part of or all of the second portion using the apparatus. FIG. 4 may be regarded as schematically depicting the scenario in which the apparatus removes the entirety of the second portion. FIG. 5 schematically depicts the scenario in which part of the second portion is removed, leaving a remainder defining a protrusion 224 which protrudes from the second surface 216 along the longitudinal axis 218.

By ensuring that the recess 214 has a minimum width 219 perpendicular to the longitudinal axis 218 of at least about 6 mm, such as at least about 9 mm, more of the second portion may be removed from the shaft 220 because the recess 214 may be wide enough for a

suitable apparatus to be protruded into the recess 214 and used to remove the second portion, or part of the second portion, as close as possible to the second surface 216.

Any suitable apparatus may be used for this purpose, provided that the dimensions of the apparatus permit its insertion into the recess 214 having such a minimum width 219, and once received within the recess 214, the apparatus is capable of removing, for example cutting off, the second portion.

Counterintuitively, the key to maximizing the space in the recess 214 along the longitudinal axis 218 is thus providing a recess 214 which is wide enough in directions perpendicular to the longitudinal axis 218. By the recess 214 having a minimum width 219 of at least about 6 mm, such as at least about 9 mm, the recess 214 may be wide enough for a suitable apparatus to remove at least part of the second portion while the apparatus is located within the recess 214.

In a non-limiting example, at least the second portion of the shaft 220 is formed from glass, and the apparatus comprises a glass knife or a flame cutting apparatus, which glass knife or flame cutting apparatus is insertable into the recess 214 and capable of removing part of or all of the second portion while the apparatus is inside the recess 214. Examples of such an apparatus will be described in more detail herein below with reference to FIGs. 9A, 9B, 10, 11, 12A, and 12B.

In a second set of examples, the arranging of the envelope 202 and the stem assembly 204, 220 may not require the shaft 220 to have a second portion, in which case removal of the second portion is not required in order to provide more space in the recess 214 along the longitudinal axis 218. FIG. 4 may thus alternatively be regarded as schematically depicting this scenario.

Because no part of any such second portion is present in the recess 214, no removing step, for example using the abovementioned apparatus, is required. This may mean that the minimum width 219 of the recess 214 can be relatively small, for example about 6 mm. Such a relatively small minimum width 219 may, for instance, be particularly suitable for certain envelope 202 shapes, for example relatively narrow profile envelope 202 shapes, such as Type C (candle), and relatively narrow bases, such as an E14 base. Moreover, in spite of the minimum width 219 of the recess 214 being relatively small, the absence of any protrusion 224 protruding within the recess 214 from the second surface 216 along the longitudinal axis 218 may assist the recess 214 to have sufficient space along the longitudinal axis 218 which can be used, for example, to accommodate the driver.

The recess 214 may have a maximum width 223 perpendicular to the longitudinal axis 218 of about 25 mm. By the width of the recess 214 being less than or equal to about 25 mm, the compatibility of the stem 204 with the adjoining cap 203, such as the above-described screw cap 203 or bayonet cap 203, for mounting the lighting device 200 in a suitable complementary standard fitting, may be facilitated. A maximum width 223 of about 25 mm may render the stem 204 compatible with, for instance, a relatively large, e.g. E40, base.

The term “about” in the present context may, for example, mean that a tolerance of ± 0.5 mm is applied to the respective measurement.

A relatively wide recess, for example a recess having a relatively large minimum width 219, may not require a specially designed apparatus to remove the second portion of the shaft 220, when such a second portion is used during arranging of the stem assembly 204, 220 and the envelope 202. Moreover, a relatively large lateral space may be available to, for instance, accommodate the driver.

The recess 214 may be at least partly delimited by the second surface 216. In some examples, such as that shown in FIG. 5, a protrusion 224 protrudes from the second surface 216 along the longitudinal axis 218. The protrusion 224 may, in the first set of examples, be left following removal of part of the second portion of the shaft 220, as previously described.

A length 221 of the recess 214 along the longitudinal axis 218 from the second surface 216 when the protrusion 224 is not present as shown in FIG. 4, or from an extremity 225 of the protrusion 224 when such a protrusion 224 is present as shown in FIG. 5, to a position aligned with an outermost periphery 227 of the stem 204 may be greater than 8 mm, such as greater than 8.5 mm, for example greater than 8.75 mm. It is noted that in the non-limiting examples shown in FIGs. 1 to 5, the lowermost portion 229 of the stem 204 may terminate at the outermost periphery 227.

The term “greater than 8 mm” in this context may, for example, exclude the length 221 being equal to 8.0 mm. Hence the length 221 may be expressed as “>8.0 mm”. The length 221 dimension of the recess 214 will be further discussed herein below with reference to FIG. 13.

Removal of the second portion of the shaft 220 as close as possible to the second surface 216 may effectively permit lengthening of the recess 214, such that its length 221 is greater than 8 mm.

Alternatively or additionally, the length 232 of the protrusion 224 from the second surface 216 along the longitudinal axis 218 may be, for example, less than about 10 mm, for example, less than about 5 mm, such as less than 2 mm.

FIG. 6 schematically depicts arranging of the envelope 202 and the stem assembly 204, 220 during manufacturing of the lighting device 200. In this non-limiting example, the shaft 220 comprises the above-described second portion 222. The second portion 222 may, for example, have a width, for example diameter, of about 2 mm to about 5 mm, such as 2 mm to about 3.5 mm.

The second portion 222 may, for instance, aid alignment of the envelope 202 and the stem assembly 204, 220, and/or provide a convenient part of the stem assembly 204, 220 which can be gripped during the arranging. At least part of the second portion 222 may be subsequently removed, for example by cutting off part of or all of the second portion 222, to provide more space in the recess 214, as previously described.

The second portion 222 may, for instance, provide the further function of permitting gas filling/evacuation of the cavity 208. Whilst not visible in FIG. 6, at least the second portion 222 of the shaft 220 may be hollow such that fluid communication can be established between the cavity 208 and part, such as an end, of the second portion 222. The second portion 222 may thus be used to connect the cavity 208 with a gas evacuation device (not visible in the Figures), such as a vacuum pump, and/or with a source of the gas or gases (not visible in the Figures) to be trapped in the cavity 208.

In other examples, when such a second portion 222 is used, the second portion 222 may be in the form of a solid shaft or may be hollow, but in the latter case the hollow portion(s) 211 of the second portion 222 may not be in fluid communication with the cavity 208. For example, a blind in the shaft 220 may prevent such fluid communication with the cavity 208. In such examples, removal of the second portion 222 need not involve forming a seal to prevent fluid communication between the recess 214 and the cavity 208 via, in other words through, the shaft 220. Obviation of the requirement to form such a seal may permit the second portion 222 to be removed at a position closer to the second surface 216. More space may therefore be provided in the recess 214, for instance for the driver.

In a non-limiting example, at least the second portion 222 of the shaft 220 may be formed from a glass rod or a glass tube. In such examples, the removing of the second portion 222 may comprise flame cutting or using a glass knife to cut the glass rod or the glass tube.

A glass knife may, for example, be used to remove the second portion 222 when the second portion 222 is formed from a glass rod, or when the second portion 222 is formed from a glass tube but the hollow portion 211 of the glass tube is not in fluid communication with the cavity 208. In this case, no seal is required at or proximal to the second surface 216 so that more space can be provided in the recess 214.

In examples in which neither the second portion 222 nor the stem 204 provides fluid communication with the cavity 208 following arranging of the stem assembly 204, 220 and the envelope 202, an alternative way of establishing such fluid communication may be provided when evacuation and/or gas filling of the cavity 208 is desired. As shown in FIG. 7, an opening 226 may be provided in the envelope 202, in addition to the aperture defined by the mouth portion 231 of the envelope 202 into which the stem assembly 204, 220 is received during the arranging. This opening 226 may be used to evacuate and/or supply gas to the cavity 208. Subsequent closing, for example sealing, of the opening 226 may trap the gas or gases inside the cavity 208.

A tube 228 may, for example, extend from the opening 226, which tube 228 may serve as a connector to the vacuum source and/or the source of the gas or gases to be trapped in the cavity 208 of the lighting device 200. In a non-limiting example, a glass tube 228 extends from the opening 226. The closing of the opening 226 in this example comprises sealing the glass tube 228 at or proximal to the opening 226.

As shown in FIG. 7, the opening 226 opposes the stem 204 across the cavity 208, which may facilitate manufacturing of the lighting device 200, and maintain rotational symmetry of the lighting device 200, and thus uniformity of luminous output around the circumference of the envelope 202, following closing of the opening 226. In other non-limiting examples, the opening 226, and the tube 228 if present, may be positioned at a different position on the envelope 202.

Turning to FIG. 8, the sealing of the opening 226 may comprise forming a further protrusion 230 on the envelope 202. In some examples, the further protrusion 230 may be subsequently removed, for example by grinding using a suitable glass grinder when the further protrusion 230 is formed from the glass of the glass tube 228/glass envelope 202.

Removal of the further protrusion 230 may assist to maintain relatively uniform optical transmissivity across the envelope 202, since the further protrusion 230 may otherwise attenuate and/or scatter light to a greater degree than other portions of the envelope 202. Removal of the further protrusion 230 may also improve the aesthetic appearance of the lighting device 200. In other examples, the further protrusion 230 may remain on the envelope 202 following manufacturing of the lighting device 200.

FIG. 8 shows the elongate support member 210 supporting a solid state lighting source 212 which is in the form of a LED filament. A connecting member 234 may connect the LED filament(s) 212 to the elongate support member 210. Electrical connections 236A, 236B, in this example comprising wires, may extend through the stem body 205 of the stem

204, thereby to connect the LED filament(s) 212 with suitable control circuitry external to the cavity 208, as previously described. In a particular example, the electrical connections 236A, 236B may connect the LED filament(s) 212 to a driver which is at least partly accommodated in the recess 214.

5 Each of the at least one LED filament 212 may comprise a plurality of solid state lighting elements (not visible in the Figures), for example light emitting diodes, arranged along a strip, such as a ceramic strip. The solid state lighting elements may, for example, be relatively narrowly spaced such that, when the LED filament 212 is illuminating, the lighting is perceived to be provided continuously along the entire LED filament 212, rather than intermittently by
10 individual solid state lighting elements.

The ceramic strip and the solid state lighting elements may, for example, be covered with silicone colloid or another optically transmissive material, which was blended with a phosphor for modifying the spectral composition of the, typically blue, light produced by the solid state lighting elements into warmer yellow tones, similar to the lighting effect produced
15 by incandescent filament bulbs. Other suitable configurations of the LED filament(s) 212 will be apparent to the skilled person.

The greater space provided in the recess 214 may, for instance, permit more of the driver to be accommodated in the recess 214. Alternatively or additionally, the driver may include more elaborate circuitry for controlling the solid state lighting source(s) 212, since the
20 additional space required by such more elaborate circuitry may be accordingly provided in the recess 214. The overall effect may be to improve the lighting and/or lighting control delivered by the lighting device 200.

Whilst one LED filament 212 is visible in FIG. 8, the lighting device 200 may comprise two, three, four, five, six, seven, eight, or more LED filaments 212. When a plurality
25 of LED filaments 212 are included in the lighting device 200, they may, for example, be evenly spaced apart from each other around the perimeter of the elongate support member 210. This may provide a luminous output which mimics that of incandescent filament bulbs.

When a plurality of LED filaments 212 is used, each of the LED filaments 212 may be identical or the LED filaments 212 may be different from each other, for example producing
30 different colored luminous outputs, white light outputs with different color temperatures, and so on. Alternatively or additionally, each of the solid state lighting elements of an LED filament 212 may be identical to each other or the solid state lighting elements may be different from each other, for example producing different colored luminous outputs, white light outputs with different color temperatures, and so on.

Each solid state lighting source 212, e.g. each LED filament, (when a plurality of solid state lighting sources 212 are included in the lighting device 200) and/or each solid state lighting element included in each solid state lighting source 212 may be individually addressable such that the luminous output of the lighting device 200 may be configurable. To this end, the lighting device 200 may include relatively elaborate driver circuitry which can be at least partly accommodated in the recess 214, as previously described.

In other non-limiting examples, in order to achieve homogeneous luminous output across the envelope 202, the solid state lighting sources 212, e.g. LED filaments, may be identical to each other, and arranged to be switched on or off in unison.

The driver may comprise components such as capacitors, resistors, a printed circuit board (PCB), etc., whose exterior surfaces have different colors. The colors of the external, e.g. painted, surfaces of such components necessarily mean that some visible wavelengths of light are absorbed, and the remaining visible wavelengths corresponding to the perceived color of the external surface are reflected. Visible wavelengths of light are in the range of 380 to 700 nm. One solution is to use the driver components with an already reflective surface, for example, keeping the aluminum housing of a capacitor bare. But such components are either not always available or costing additional labor to remove the color outer layer of the commercial standardized components.

In one set of examples, one or more surfaces of the stem 204, and preferably the second surface 216 delimiting the recess 214, is or are coated with a reflective material. In this manner, the absorption of light by components of the driver can be minimized or prevented.

The term “reflective material” in this context is intended to mean a reflective material which does not absorb or only negligibly absorbs visible wavelengths of light.

The reflective material may provide diffuse reflectance. Thus, the reflected light is scattered at different angles by the reflective material included in the coating. In this case, the reflective material may, for example, comprise TiO_2 . The coating may, for instance, comprise the reflective material providing diffuse reflectance, such as TiO_2 , and a polymeric binder. In a non-limiting example, the coating comprises an acrylic resin doped with TiO_2 .

Alternatively, the reflective material may provide specular reflectance. In this case, the coating comprises, or consists of, a specular metal coating, such as silver or aluminum.

In an alternative set of examples, the driver is covered with a reflective sleeve arranged to reflect light towards the optically transmissive stem 204. This also assists to minimize or prevent the above-described light absorption by the colored external surfaces of the components of the driver.

The term “reflective sleeve” in this context is intended to mean a reflective sleeve whose exterior does not absorb or only negligibly absorbs visible wavelengths of light.

The reflective sleeve may comprise a reflective material, such as a reflective material providing specular or diffuse reflectance. Examples of reflective materials providing diffuse reflectance include TiO_2 and CaCO_3 . Examples of reflective materials providing specular reflectance include metals such as silver or aluminum. An outer surface of the sleeve may, for example, be coated with a specular metal coating.

The sleeve can be rigid or flexible. The sleeve may, for example, comprise a polymeric, e.g. PTFE, cap, or a polymeric, e.g. PET, cover. The reflective material can, for example, be included in, or be coated onto the exterior of, such a cap or cover. In non-limiting examples, the cap is a PTFE cap doped with CaCO_3 , or the cover is a PET cover doped with CaCO_3 . Other exemplar sleeves can be white thermal shrink tubes, white tapes, formed with injection moulding or extrusion with e.g., PBT (Polybutylene terephthalate) or PPA (Polyphthalamide), etc.

Light from the at least one solid state lighting source 212 incident on the reflective surface of the coating of reflective material or on the reflective sleeve may, rather than being absorbed by any colored surfaces of the components of the driver, be reflected from or through the stem 204, and ultimately through the envelope 202 of the lighting device 200. Thus, the overall optical efficiency of the lighting device 200 may be improved. In particular, such modification may improve the overall optical efficiency of the lighting device 200 by around 1%. FIGs. 9A and 9B provide views of an apparatus 300 according to an example. The apparatus 300 may be used for removing the second portion 222 of the shaft 220 of the stem assembly 204, 220. As shown in FIGs. 9A and 9B, the apparatus 300 comprises a housing 302 for inserting axially into the recess 214. The housing 302 delimits an aperture 304 for passing the shaft 220, and in particular the second portion 222 of the shaft 220, therethrough. The diameter of the aperture 304 may be, for example, at least 2 mm, such as at least 3 mm, for example at least 5 mm.

A flame outlet 306 is supplied with a combustible gas, such as a mixture of oxygen and propane, via a conduit 308. The arrow 307 represents the direction of flow of the combustible gas through the conduit 308 towards the flame outlet 306. The flame outlet 306 is arranged to direct a flame radially from the housing 302 into the aperture 304. In this manner, the flame is directed towards the shaft 220 when the shaft 220 is passed through the aperture 304. The heat of the flame may be carefully controlled to assist to minimize the risk of damage to other components of the lighting device 200 while the second portion 222 is being removed.

As shown in FIG. 9B, the combustible gas may enter an annular channel 313 within the housing 302 which feeds the combustible gas to the flame outlet 306, which in this non-limiting example extends around a perimeter of the aperture 304. By the flame outlet 306 extending around at least part of the perimeter of the aperture 304, the shaft 220 may be evenly heated around its circumference, which may facilitate removal of the second portion 222.

The housing 302 may prevent direct exposure of the stem 204 to the flame being directed from the flame outlet 306. Thus, the housing 302 may assist to prevent exposure of the second surface 216 to the flame. The housing 302 may be formed from any suitable heat resistant material, such as a metal, for example copper, or metal alloy, for example brass.

By the housing 302 being insertable into the recess 214 of the stem 204, the second portion 222 of the shaft 220 may be removed from a position which is relatively close to the second surface 216. This may assist to provide greater space inside the recess 214, as previously described.

The width 309 of the housing 302 in radial directions may, for example, be in the range of 6 mm to 25 mm, such as 6 mm to 17 mm, in order for the housing 302 to be insertable into the recess 214.

An axial distance 310 from a distal external surface 312 of the housing 302 to a midpoint 314 of the flame outlet 306 may, for example, be less than 10 mm, such as less than 5 mm, for example, less than 2 mm. The distal external surface 312 of the housing 302 may approach, and preferably not contact, the second surface 216. Accordingly, such a maximum axial distance 310 may assist to ensure that the axial protruding of the protrusion 224 derived from the second portion 222 of the shaft 220 may be minimized.

FIG. 10 schematically depicts the apparatus 300 being used to remove the second portion 222 of the shaft 220 following arranging of the stem assembly 204, 220 and the envelope 202. As shown in FIG. 10, the apparatus 300 flame cuts the second portion 222 at a point 238 which aligns with the flame outlet 306 of the apparatus 300. As shown in FIG. 10, the point 238 is proximal to the second surface 216.

As shown in FIG. 10, the conduit 308 may additionally enable manipulation of the apparatus 300, and in this case insertion of the housing 302 into the recess 214. To this end, the conduit 308 may comprise a rigid tube, for example formed from a metal or metal alloy. Alternatively or additionally, the apparatus 300 may comprise a dedicated member (not visible in the Figures) which axially extends from the housing 302, and assists with guiding the housing 302 into the recess 214, holding the housing 302 within the recess 214 during flame

cutting of the second portion 222, and subsequently withdrawing the housing 302 from the recess 214.

The apparatus 300 may be suitable for flame cutting solid and hollow glass shafts 220. When the shaft 220 comprises a hollow glass tube, the portion of glass 238 aligning with the flame outlet 306 may melt to seal the shaft 220 at the same time as or relatively soon after the flame cutting.

FIG. 11 schematically depicts the apparatus 300 shown in FIGs. 9A and 9B being used in an exemplary manufacturing process. The arrangement shown in FIG. 11 may be employed subsequently to trapping of the gas, for example the noble gas or gases, in the cavity 208. The respective conduits 308 of the apparatuses 300 shown in FIG. 11 extend through holes 324 of a processing jig 326 and into the respective recesses 214 of the lighting devices 200 being fabricated. The housing 302 can be extended into the recess 214 by a mechanism (not visible) applying a force to the conduit 308 to push the apparatus 300 in the direction of the recess 214. The mechanism may subsequently retract the apparatus 300 once the second portion 222 or part of the second portion 222 has been removed.

A gripper 328 is configured to withdraw the second portion 222 or part of the second portion 222 following flame cutting by the apparatus 300. When a seal is required in the protrusion 224 remaining following the removing of part of the second portion 222, the gripper 328 may withdraw the part of the second portion 222, but the apparatus 300 may remain heating the protrusion 224 for a short period, such as a few seconds, thereafter to form the seal.

In the non-limiting example shown in FIG. 11, the apparatuses 300 and the lighting devices 200 being fabricated are orientated such that the elongate support member 210 extends from the first surface 206 upwardly. This upright orientation may facilitate handling of the lighting devices 200 and their constituent parts, such as the stem assembly 204, 220 and the envelope 202, during manufacturing. Moreover, heat from the apparatuses 300 is primarily directed towards the respective second portions 222, thereby minimizing the risk of damage to the respective stem bodies 205. The solid state light source 212 is not shown in FIGs 10 and 11 for the sake of clarity.

In an alternative non-limiting example, the apparatuses 300 and the lighting devices 200 being fabricated are orientated such that the elongate support member 210 extends from the first surface 206 downwardly. Heated air/gas from the flame outlets 306 of the apparatuses 300 may thus rise in the recess 214 away from the envelope 202, thereby to further minimize the risk of the heat damaging components of the lighting device 200 during removing of the second portion 222.

FIGs. 12A and 12B depict an apparatus 300 which, in this particular non-limiting example, further comprises a cooling system 316, 318, 320 for cooling the housing 302 while the combustible gas is being burned at the flame outlet 306. The cooling system 316, 318, 320 may further assist to provide greater space inside the recess 214 because the housing 302 of the apparatus 300 may be brought closer to the second surface 216 than, for example, when no cooling system 316, 318, 320 is included in the apparatus 300. This may be due to the cooling system 316, 318, 320 assisting to minimize the risk of the housing 302 transferring heat to, and thus damaging, other components of the lighting device 200 while the second portion 222 is being removed.

In the example shown in FIGs. 12A and 12B, the cooling system 316, 318, 320 comprises: an inlet 316; a channel 318 within the housing 302 arranged to receive, from the inlet 316, fluid for cooling the housing 302. The arrow 317 represents the direction of flow of the fluid towards the channel 318.

The fluid is heated in the channel 318 by heat generated from burning of the combustible gas at the flame outlet 306. The heated fluid then leaves the channel 318 via the outlet 320, as represented by the arrow 321. The fluid may, for example, comprise or consist of water, although alternative fluids for cooling the housing 302 will be immediately apparent to the skilled person.

Such a heat exchange/cooling system 316, 318, 320 may provide a convenient way of cooling the housing 302, and particularly its external surfaces, including the upper external surface 312, facing the recess 214 of the stem 204. This may enable the housing 302 to be brought closer to the second surface 216, such that the second portion 222 can be removed at a point 238 which is closer to the second surface 216. Alternatively or additionally, the cooling system 316, 318, 320 may permit a hotter flame to be used for more rapid flame cutting.

FIG. 13 schematically depicts a step in manufacturing of a lighting device 200, for comparison with FIGs. 10 and 11. FIG. 13 depicts a burner nozzle 330 directing a flame 332 into the recess 214. In other words, it is the flame 332 which is “inserted” into the recess 214, not the burner nozzle 330. At its most slanted, but still not contacting the second portion 222, the cutting flame can only cut the second portion 222 at position 240, which is at an axial distance h from the burner nozzle 330. By contrast, a sufficiently wide recess 214, and use of an apparatus, such as the apparatus 300 described above, for removing the second portion 222 while the apparatus, or a relevant cutting part of the apparatus, is received therein, means that the second portion 222 is removable at a point 238 which is closer to the second surface 216.

In this manner, more space is made in the recess 214 along the longitudinal axis 218, as previously described.

Assuming that the burner nozzle 330 is angled at 45° to the longitudinal axis 218, then the maximum h achievable with this arrangement, $h_{\max} = (D-d)/2$, where d is the thickness of the second portion 222.

When, for example, $D = 18$ mm, and $d = 3$ mm, $h_{\max}$ may be 7.5 mm. When, for example, $D = 9$ mm, and $d = 2$ mm, then $h_{\max}$ may be 3.5 mm. In both cases, the length 221 of the recess 214 along the longitudinal axis 218 from the extremity 225 of the resulting protrusion 224 to a position aligned with an outermost periphery 227 of the stem 204 is less than 8 mm.

FIG. 14 provides a flowchart of a method 400 according to an example. The method 400 is for manufacturing a lighting device, such as the lighting device 200 described above. The method 400 comprises providing 410 an envelope which allows light to pass therethrough. Block 420 represents providing a stem assembly comprising a stem, and a shaft extending along a longitudinal axis. A first portion of the shaft extends from a first surface of the stem. This first portion may ultimately define the elongate support member 210 of the lighting device 200 described above. A second surface of the stem at least partly delimits a recess in the stem. The recess has a minimum width perpendicular to the longitudinal axis of at least about 6 mm, as previously described.

The method 400 comprises supporting 430 at least one solid state lighting source on the first portion. Block 440 represents arranging the envelope and the stem assembly such that the first portion extends from the first surface into a cavity delimited by the envelope and the first surface.

In the above-described first set of examples, a second portion of the shaft may extend in the recess from the second surface. In this case, the method 400 may further comprise, subsequent to the arranging 440 of the envelope and the stem assembly, removing 460 at least part of the second portion. The removing 460 may, for example, comprise receiving an apparatus for removing the at least part of the second portion in the recess, and using the apparatus to remove the at least part of the second portion while the apparatus is received in the recess. The apparatus may, for example, be the apparatus 300 described above in relation to FIGs. 9A, 9B, 10, 11, 12A, and 12B.

In the above-described second set of examples, no second portion may be employed, such that the method 400 does not include the removing step 460.

The method 400 may further comprise trapping 450 a gas, such as a noble gas or gases, in the cavity. The gas may be trapped in the cavity by, for example, the envelope being

sealingly secured to the stem. Moreover, the gas may be prevented from leaking from the cavity into the recess through the shaft. When, for example, the second portion is in the form of a hollow tube, the removing of the hollow tube may be implemented in such a way as to limit or prevent fluid communication between the recess and the cavity via the shaft. This may involve forming a seal at or proximal to the second surface, as previously described.

Alternatively, when the second portion is in the form of a solid rod, or a hollow tube whose hollow portion(s) does or do not fluidly communicate with the cavity, the second portion may be removed in any suitable manner as close as possible to the second surface. In such examples, the envelope 202 may, for instance, have an opening 226 for evacuating/gas filling the cavity 208 other than via the stem assembly 204, 220, as previously described in related to FIG. 7.

The method 400 may comprise receiving 470 at least part of a driver for controlling the at least one LED filament in the recess. The receiving 470 of the driver within the recess may be implemented subsequently to the removing of the second portion, when such a second portion is used in the manufacture of the lighting device.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

- 5 1. A lighting device (200) comprising:
a glass envelope (202) which allows light to pass therethrough;
a stem (204) to which the envelope is secured, the stem having a first surface
(206), wherein a cavity (208) is delimited by the envelope and the first surface;
10 a first portion (210) of a shaft (220) extending from the first surface into the
cavity, the first portion extending along a longitudinal axis (218);
at least one solid state lighting source (212) supported by the first portion, each
of the at least one solid state lighting source being arranged to emit light towards and through
the envelope; and
a recess (214) in the stem for receiving at least part of a driver for controlling
15 the at least one solid state lighting source, the recess being at least partly delimited by a second
surface (216), wherein the recess has a minimum width (219) perpendicular to the longitudinal
axis of at least about 6 mm, wherein a protrusion (224) optionally protrudes from the second
surface along the longitudinal axis (218), and wherein a length (221) of the recess (214) along
the longitudinal axis (218) from the second surface (216) when the protrusion (224) is not
20 present, or from an extremity (225) of the protrusion when present, to a position aligned with
an outermost periphery (227) of the stem (204) is greater than 8 mm,
wherein at least part of the stem (204) is coated with a reflective material or the
at least part of the driver is covered with a reflective sleeve arranged to reflect light towards
the stem (204).
25
2. The lighting device (200) according to claim 1, wherein said at least part of the
stem (204) which is coated with the reflective material comprises the second surface (216).
3. The lighting device (200) according to claim 1 or claim 2, wherein the recess
30 has a maximum width (223) perpendicular to the longitudinal axis (218) of about 25 mm.
4. The lighting device (200) according to any of claims 1 to 3, wherein the
protrusion (224) protrudes from the second surface along the longitudinal axis (218).

5. The lighting device (200) according to any of claims 1 to 3, wherein no protrusion (224) protrudes from the second surface along the longitudinal axis (218).

6. The lighting device (200) according to any of claims 1 to 5, wherein the first portion (210) comprises a hollow tube, or is in the form of a solid rod.

7. The lighting device (200) according to any of claims 1 to 6, wherein each of the at least one solid state lighting source (212) is a LED filament; and/or wherein the lighting device comprises the driver, wherein said at least part of the driver is received in the recess (214).

8. A method (400) for manufacturing a lighting device (200), the method comprising:

providing (410) a glass envelope (202) which allows light to pass therethrough;

providing (420) a stem assembly (204, 220) comprising a stem (204), and a shaft (220) extending along a longitudinal axis (218), wherein a first portion (210) of the shaft extends from a first surface (206) of the stem, a second surface (216) of the stem at least partly delimiting a recess (214) in the stem, wherein the recess has a minimum width (219) perpendicular to the longitudinal axis of at least about 6 mm;

applying a reflective material on at least part of the stem (204), or covering at least part of a driver for controlling at least one solid state lighting source (212) with a reflective sleeve for reflecting light towards the stem;

supporting (430) the at least one solid state lighting source (212) on the first portion; and

arranging (440) the envelope and the stem assembly such that the first portion extends from the first surface into a cavity (208) delimited by the envelope and the first surface.

9. The method according to claim 8, wherein a second portion (222) of the shaft (220) extends in the recess (214) from the second surface (216), the method further comprising, subsequent to said arranging (440), removing (460) at least part of the second portion.

10. The method (400) according to claim 9, wherein the removing (460) comprises: receiving an apparatus (300) for removing said at least part of the second portion (222) in the recess (214); and

using the apparatus to remove said at least part of the second portion while the apparatus is received in the recess;

optionally wherein a length (221) of the recess along the longitudinal axis (218) from the second surface (216) when the second portion has been removed, or from an extremity (225) of a protrusion (224) defining a remainder of the second portion left following the removing, to a position aligned with an outermost periphery (227) of the stem (204) is greater than 8 mm.

11. The method (400) according to claim 9 or claim 10, wherein at least the second portion (222) of the shaft (220) is formed from a glass rod or a glass tube, and wherein the removing (460) comprises flame cutting or using a glass knife to cut the glass rod or the glass tube.

12. The method according to any of claims 8 to 11, further comprising receiving (470) the at least part of the driver in the recess (214).

13. The method (400) according to any of claims 8 to 12, further comprising trapping (450) a gas in the cavity (208); optionally wherein the gas comprises at least one of helium, neon, argon, krypton, and xenon.

14. The method (400) according to claim 13, wherein the trapping (450) comprises: filling the cavity (208) with the gas via an opening (226) in the envelope (202); and

closing the opening to trap the gas in the cavity, wherein a glass tube (228) extends from the opening and provides a fluid connection to a source of the gas, and wherein said closing comprises sealing the glass tube at or proximal to the opening; and wherein the sealing comprises forming a further protrusion (230) on the envelope; optionally wherein the method further comprises removing the further protrusion.

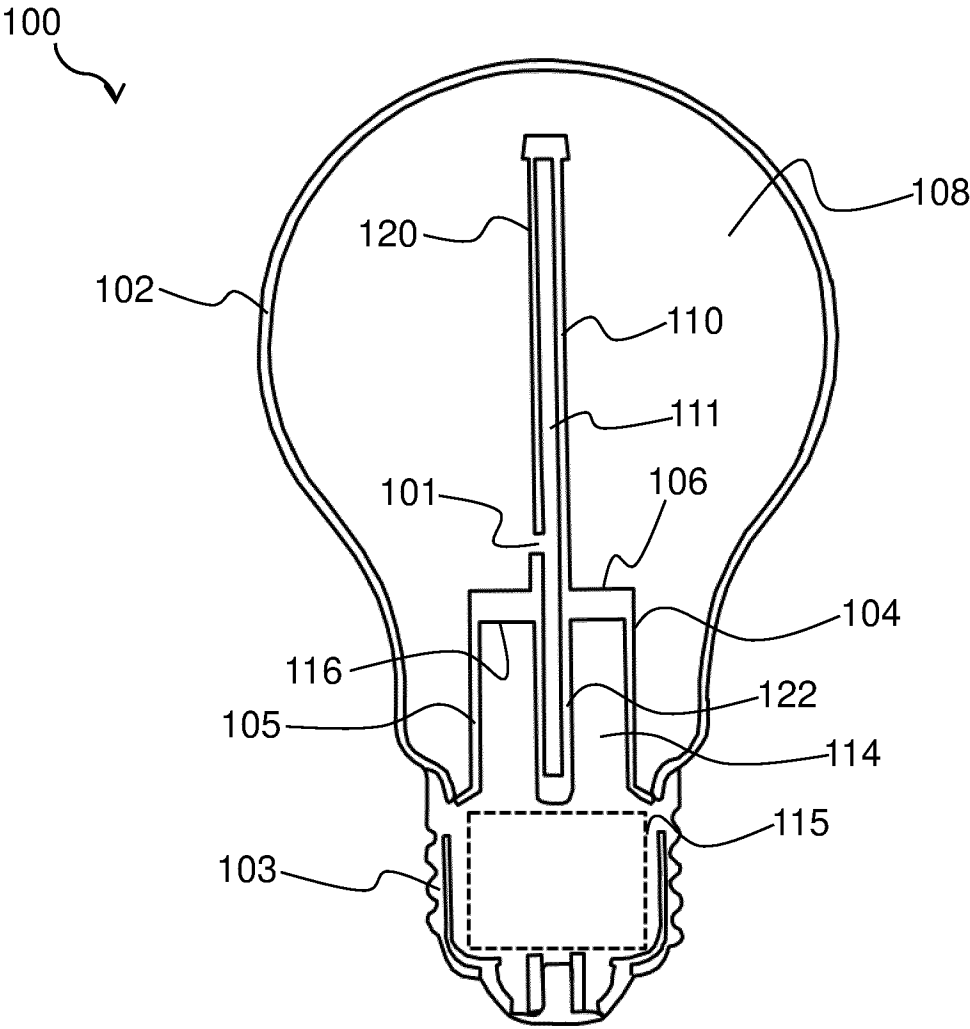


FIG. 1 (Prior Art)

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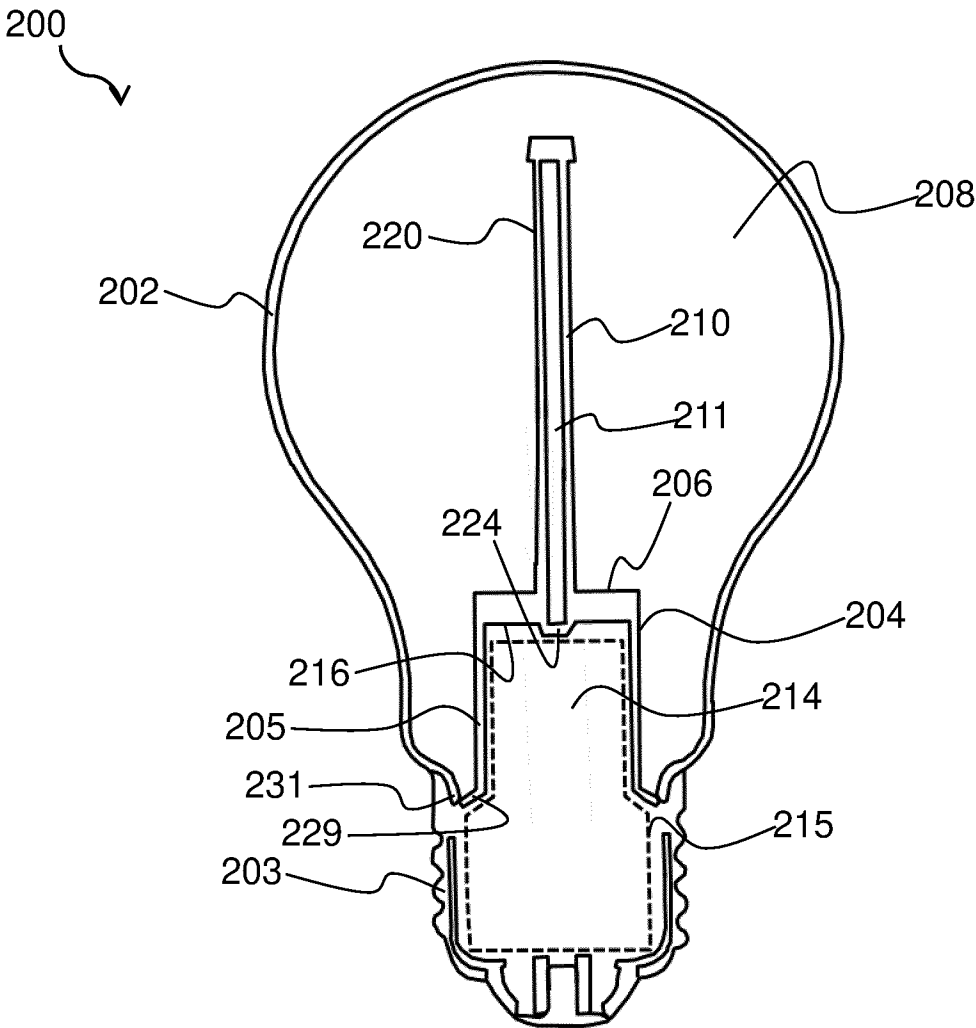


FIG. 2

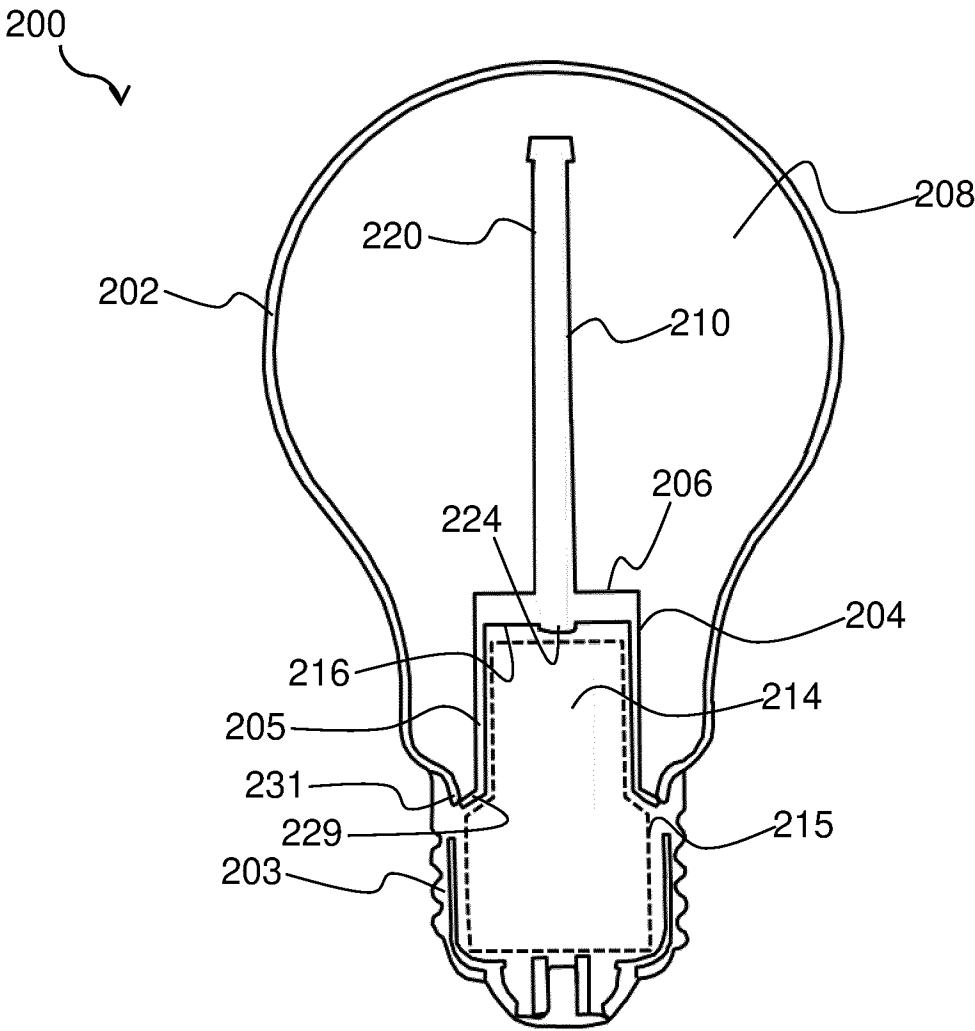


FIG. 3

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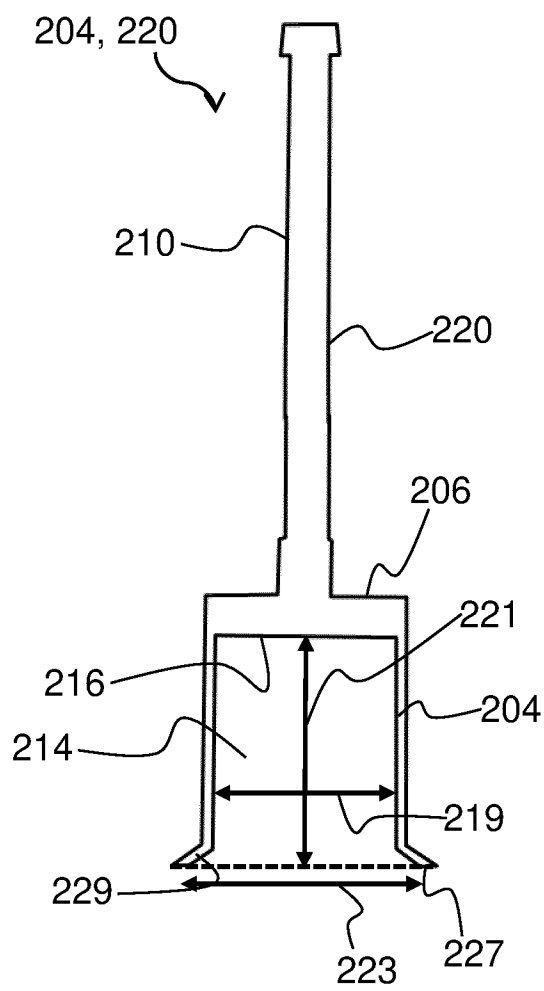


FIG. 4

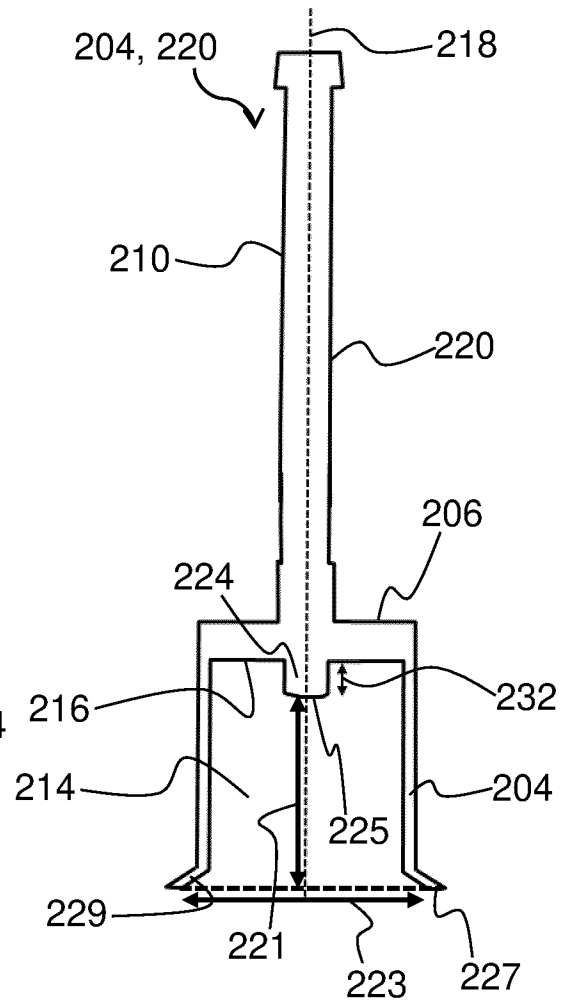


FIG. 5

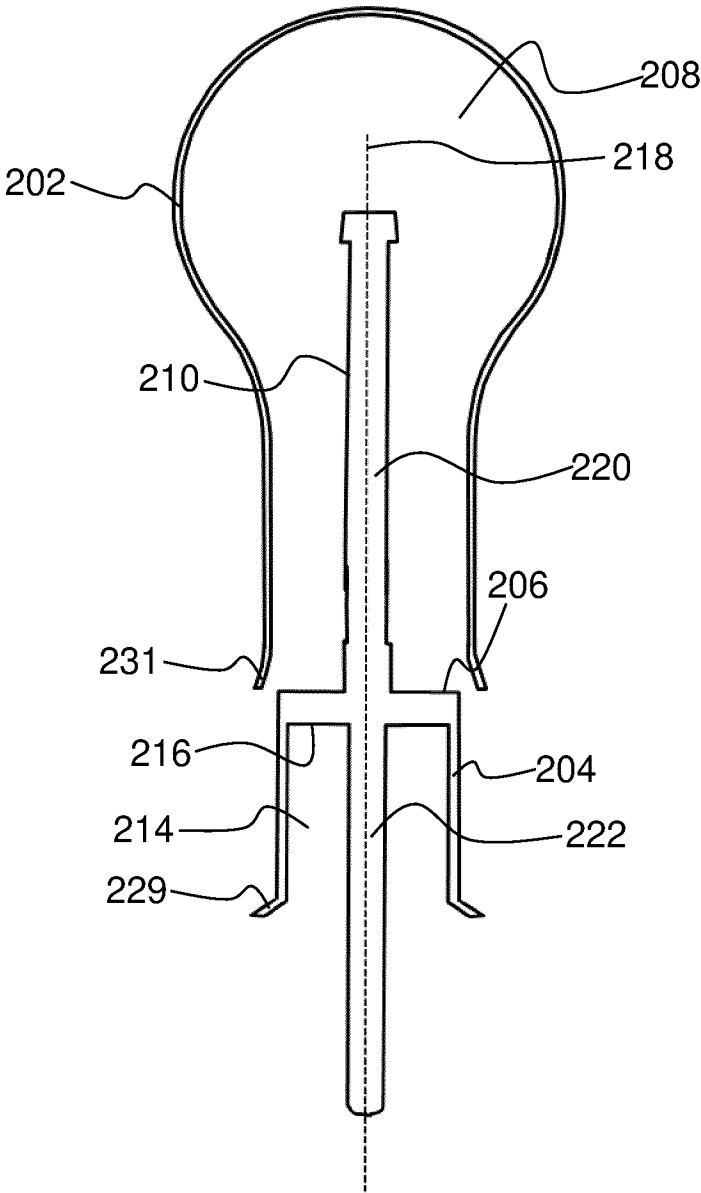


FIG. 6

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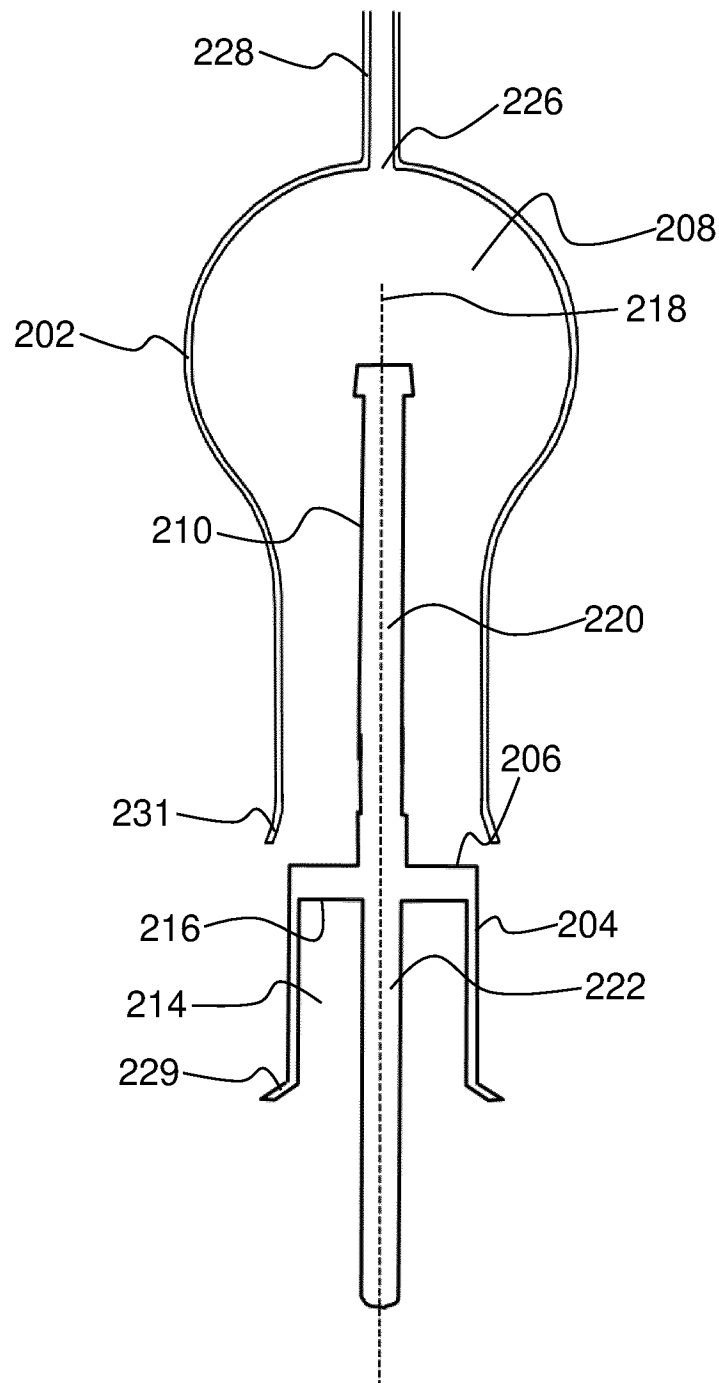


FIG. 7

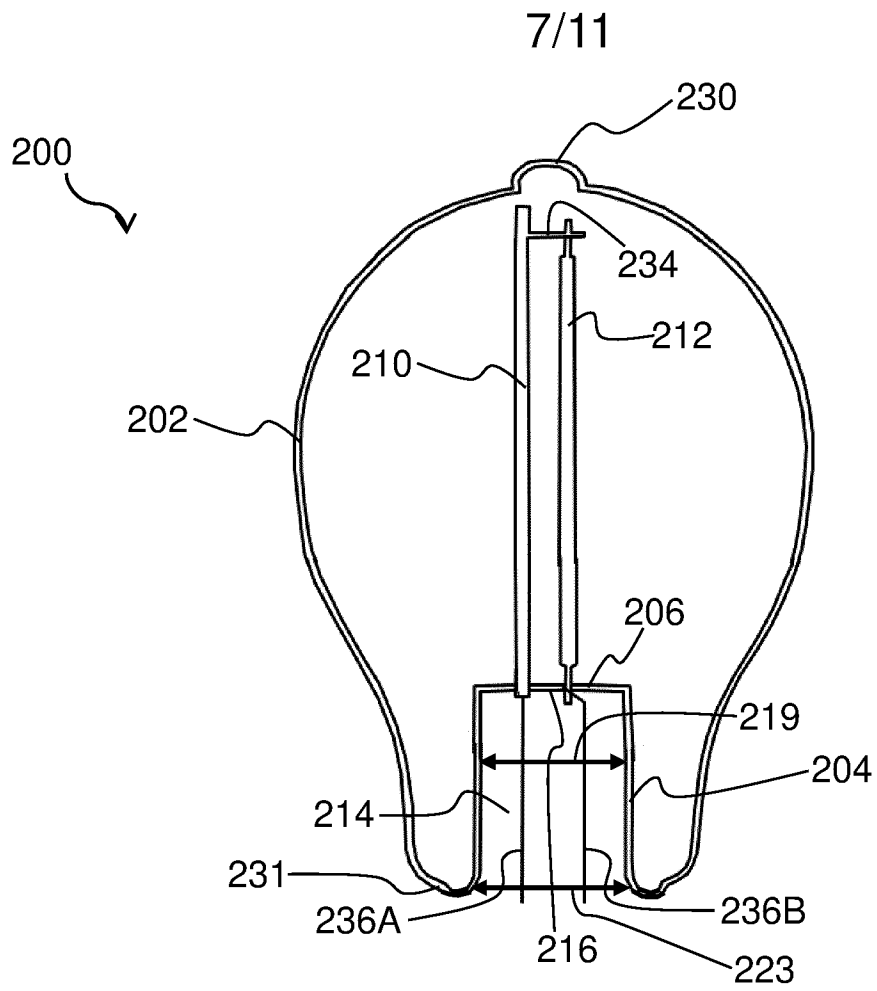


FIG. 8

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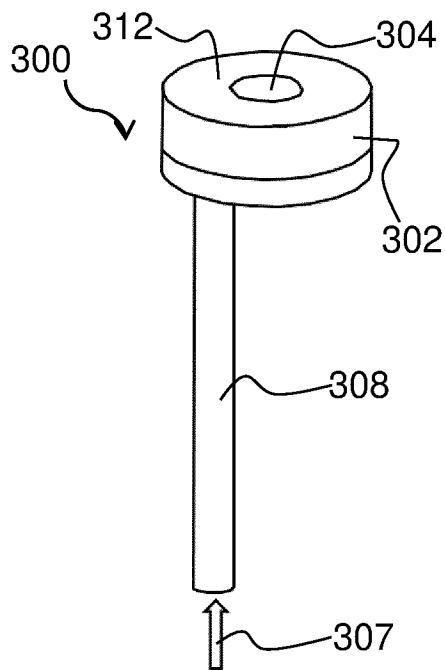


FIG. 9A

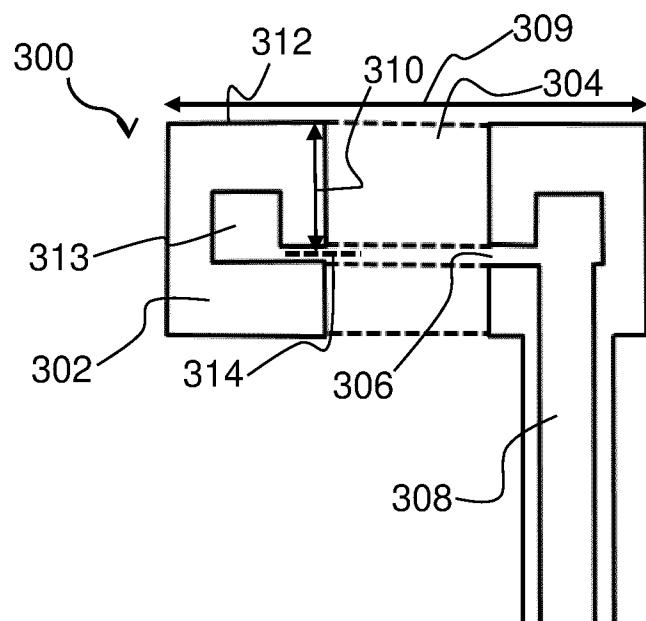


FIG. 9B

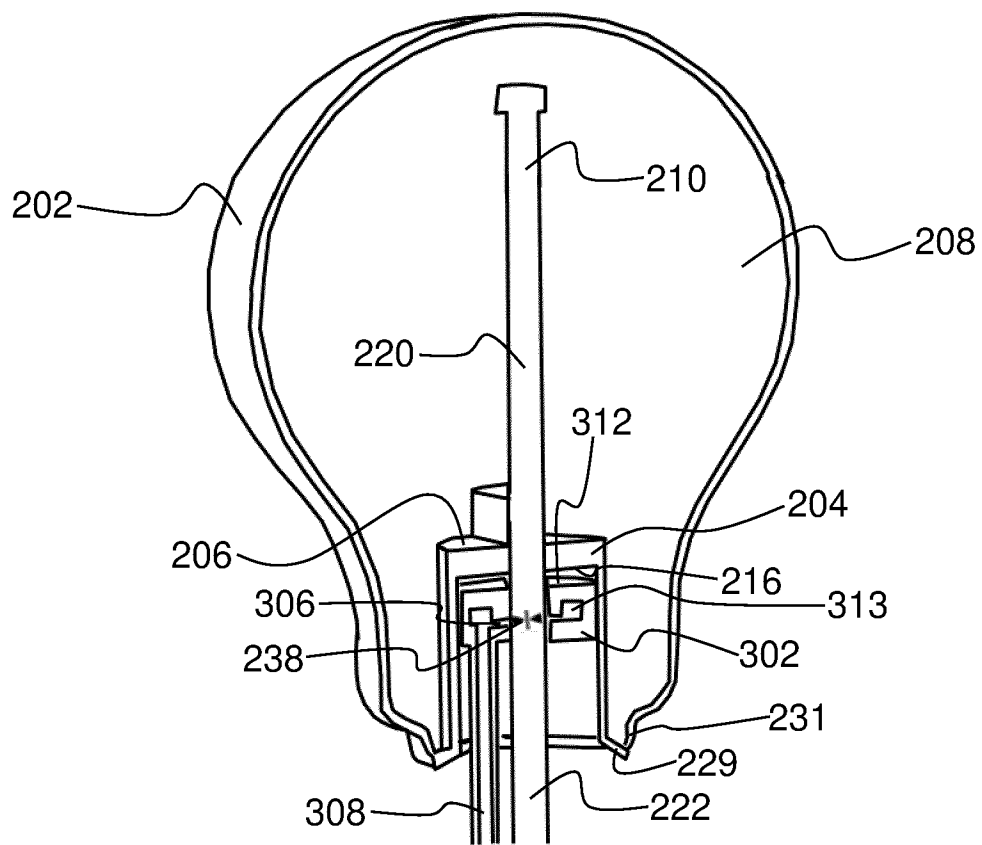


FIG. 10

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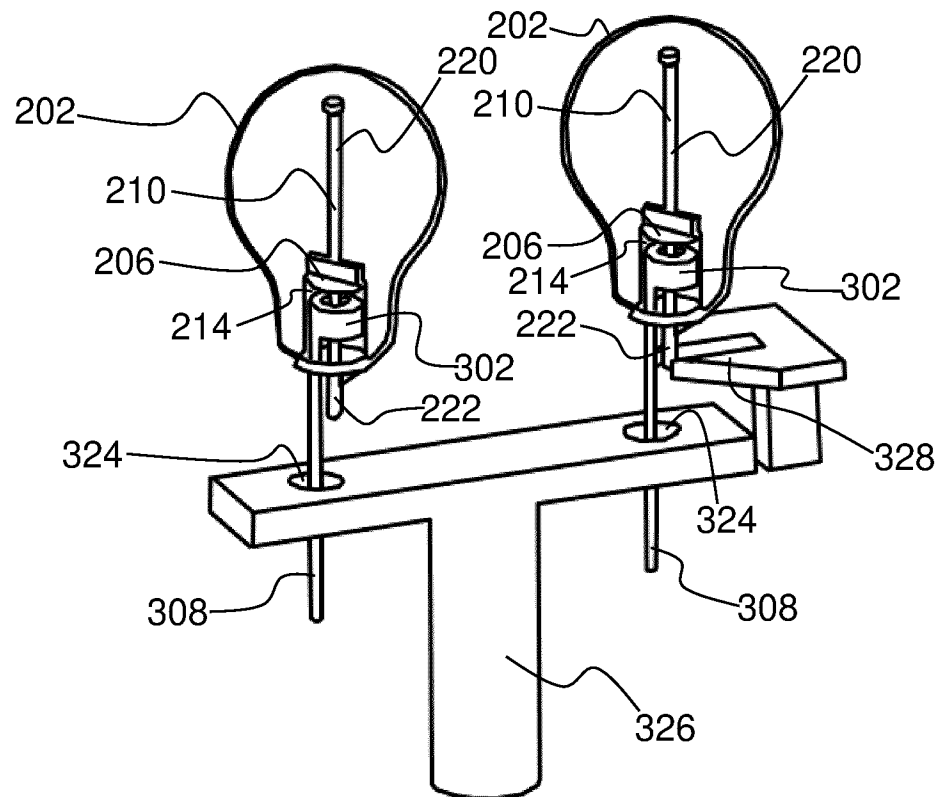


FIG. 11

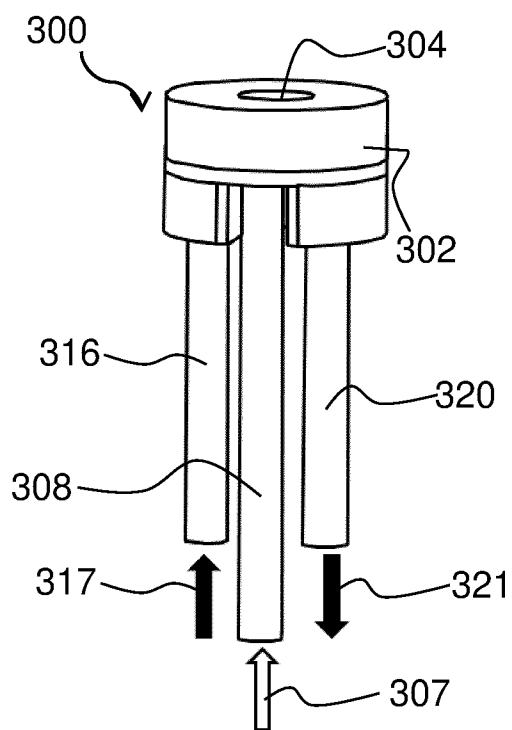


FIG. 12A

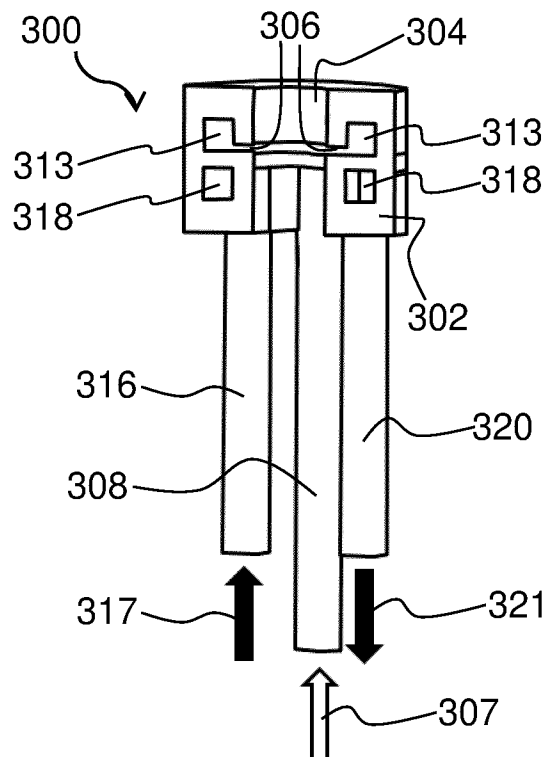


FIG. 12B

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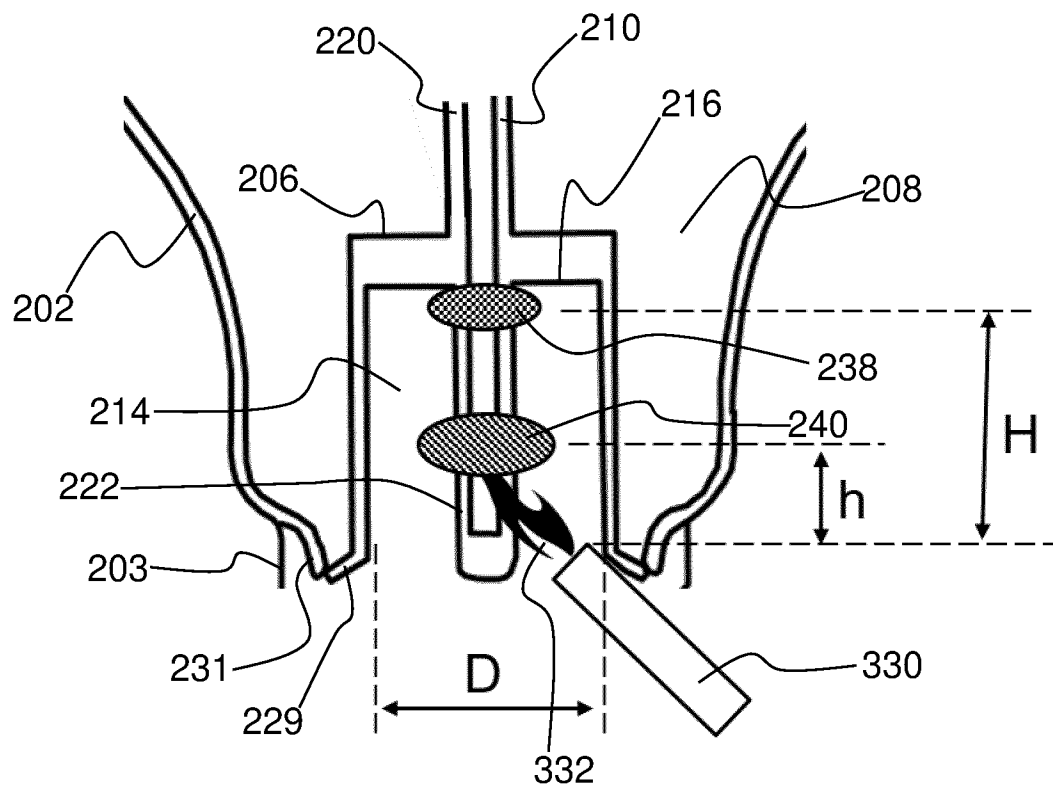


FIG. 13

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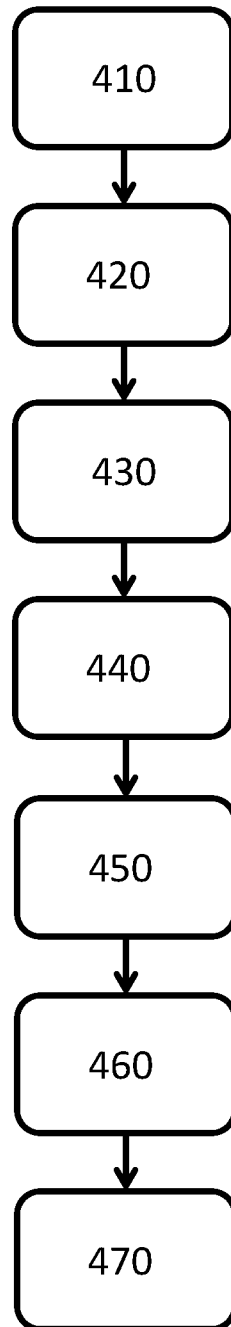
400 

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/059025

A. CLASSIFICATION OF SUBJECT MATTER INV. F21K9/232 F21K9/237 F21K9/238 F21V23/00 F21K9/90 F21K9/66 ADD. F21Y115/10 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) F21K F21V F21Y H01K Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																	
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">X Y</td> <td style="vertical-align: top;"> WO 2016/145923 A1 (GMY LIGHTING TECH CO LTD [CN]) 22 September 2016 (2016-09-22) figures 6, 7 ----- </td> <td style="vertical-align: top;"> 1-3,5-8, 12,13 14 </td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> GB 2 561 145 A (KOSNIC LIGHTING LTD [GB]) 10 October 2018 (2018-10-10) page 3, paragraphs 3, 4 page 6, paragraph 1-4 figures 1, 2 ----- </td> <td style="vertical-align: top;"> 1-13 </td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> CN 209 762 751 U (JINJIANG GENERATION GOOD PHOTOELECTRIC) 10 December 2019 (2019-12-10) figures 1, 2 ----- </td> <td style="vertical-align: top;"> 1-3,5-8, 12 </td> </tr> <tr> <td colspan="2" style="text-align: center; vertical-align: bottom;">----- -/-</td> <td></td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X Y	WO 2016/145923 A1 (GMY LIGHTING TECH CO LTD [CN]) 22 September 2016 (2016-09-22) figures 6, 7 -----	1-3,5-8, 12,13 14	X	GB 2 561 145 A (KOSNIC LIGHTING LTD [GB]) 10 October 2018 (2018-10-10) page 3, paragraphs 3, 4 page 6, paragraph 1-4 figures 1, 2 -----	1-13	X	CN 209 762 751 U (JINJIANG GENERATION GOOD PHOTOELECTRIC) 10 December 2019 (2019-12-10) figures 1, 2 -----	1-3,5-8, 12	----- -/-		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.															
X Y	WO 2016/145923 A1 (GMY LIGHTING TECH CO LTD [CN]) 22 September 2016 (2016-09-22) figures 6, 7 -----	1-3,5-8, 12,13 14															
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																	
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Date of the actual completion of the international search 29 April 2021		Date of mailing of the international search report 14/05/2021															
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Allen, Katie															

INTERNATIONAL SEARCH REPORT

International application No
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