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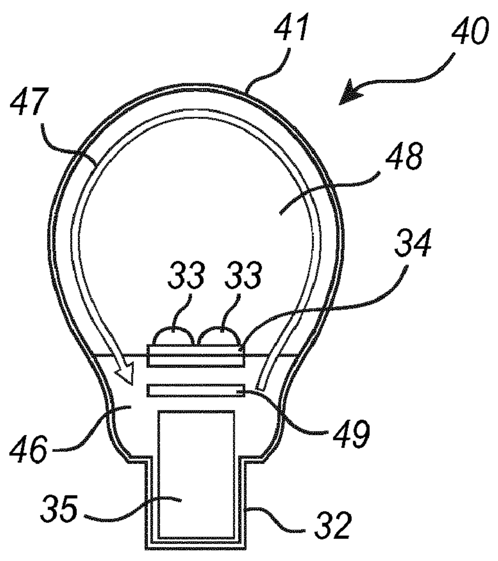

Fig. 4

(57) **Abstract**: The present invention relates to a lighting device (40, 50) comprising a housing(41), a lighting arrangement located in an inner space (48) of said housing(41), and an ionic wind generator (49, 59, 69) arranged in said inner space (48) and configured to provide a flow of gas directed along an inner surface of said housing(41).

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Lighting device

FIELD OF THE INVENTION

The present invention relates to the field of lighting devices, and in particular to the field of cooling of lighting arrangements in lighting devices.

BACKGROUND OF THE INVENTION

Lighting devices exist in all kinds of shapes and utilizing different lighting sources such as incandescent light sources, halogen light sources, fluorescent lamps and light emitting diodes (LEDs). One substantial issue with lighting devices is the generation of waste heat. An advantage with LEDs is that they are substantially more efficient than for example incandescent lamps. However, LEDs still produce heat.

The waste heat has the negative consequence of heating the light source and other electrical components, such as a light source driver, in the lighting device, potentially negatively influencing the performance of the components. In order to optimize the functionality of the electrical components of the lighting device, and in order to avoid overheating, the waste heat needs to be led away from the lighting device.

For this purpose the heat generating elements of a lighting device are typically connected to a heat sink. Generated heat is conducted from the lighting device, for example comprising LEDs, through the heat sink. The heat sink transfers heat to the ambient air by natural convection.

Another option for cooling a lighting device is to use forced convection air-cooling. This option usually relies on mechanical-to-fluid energy conversion through a mechanical fan. Drawbacks with this cooling technology are acoustic noise and short lifetime of the fan. However, it is also possible to use electrical-to-fluid energy conversion by a gas discharge to create an air flow. Different names are being used for this phenomenon: electric wind, ionic wind, corona wind, electrohydrodynamic flow, electrostatic fluid acceleration, etc. In this application, the phenomenon will be referred to as ionic wind.

Ionic wind generators have the potential of replacing mechanical fans in electronic devices comprising for example low power chips, power electronics or LEDs. This technology overcomes the acoustic noise issue. An example of how ionic wind cooling may be implemented in a lighting device is disclosed in US 2011/0285267. The document discloses an ionic wind generator being arranged to provide an air flow through heat sink fins. The heat sink is open towards the ambient air in order to enable a flow of ambient air through the heat sink fins and through the lighting device.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a lighting device utilizing ionic wind cooling. It is a further object of the invention to provide improved heat dissipation in such a lighting device.

According to a first aspect of the invention, this and other objects are achieved by a lighting device comprising a housing, a lighting arrangement located in an inner space of said housing, and an ionic wind generator arranged in said inner space and configured to provide a flow of gas directed along an inner surface of said housing.

By housing is in this context meant a body which may house the components of the lighting device. The housing typically defines the outer shape of the lighting device. The housing may be formed by different portions of different materials. The housing may e.g. comprise a light bulb and an end cap which are connected to each other.

The ionic wind generator is configured to provide a flow of gas directed along an inner surface of the housing. By inner surface is meant a surface on a portion of the housing being an outer wall, such as a light bulb.

By that the flow of gas, carrying waste heat generated by the lighting arrangement, is directed along the inner surface, the gas is forced to flow along a larger surface of the housing when compared to natural convection. The housing, being the connection between the inner space and the ambient air, functions as a heat dissipator by that heat is transferred from the gas flowing along the inner surface to the corresponding outer surface and out to the ambient air.

The ionic wind generator thus creates a flow of gas which transports heat via forced convection in an efficient way from the lighting arrangement, in particular the light sources, to the surface of the housing. Heat from a heat sink within the lighting device may also be transported.

By the larger surface of heat dissipation, due to the forced convection, a better heat dissipation is achieved when compared to natural convection within the inner space. A heat sink being incorporated in the lighting housing may thus be made smaller, providing more space for further components or for increasing a translucent portion of the housing, thus increasing the light emission area. Alternatively, the increased heat dissipation capacity may be exploited by increasing the effect of e.g. the light sources which will then also generate a larger amount of heat.

Altogether, the invention provides a better utilization of a present housing without the need for modifying the outer dimensions of the lighting device.

The lighting arrangement may comprise one or a combination of the following: a light source, a light source board, and a light source driver. Moreover, the light source may comprise one or more light emitting diodes (LEDs).

Unfortunately, there exist drawbacks with ionic wind generators of today. The lifetime is short due to contamination and oxidation of the generator electrodes e.g. due to dust, moisture, and oxygen in the surrounding air. Moreover, there is a potential ozone hazard since ozone is a bi-product of the ionic wind generation. For this purpose, the inner space of the lighting device may be closed. By a closed inner space, the disadvantages of ozone contamination of the ambient air are overcome. Moreover, the electrodes of the ionic wind generator do not suffer from contamination and oxidation to the same extent as in known solutions where ambient air is pumped by the ionic wind generator through the device.

The housing may comprise a translucent portion of a heat conducting material, wherein the ionic wind generator is arranged to direct the flow of gas along said translucent portion. The translucent portion may be a light bulb of the lighting device. The translucent portion functions both as a light transmitter and a heat dissipator. Thus, a better utilization of the translucent portion of the housing is achieved.

The translucent portion may be bulb shaped. Thus, a large heat dissipation area is provided.

In one embodiment, the ionic wind generator comprises a grounded collector and an emitter provided with a positive or negative voltage in relation to the collector. Thus, the emitter is positively or negatively charged when compared to the grounded collector. The grounded collector may be formed by a grounded portion of the lighting arrangement. Thus, the ionic wind generator becomes integrated, partly or in full, with the lighting arrangement, thereby providing a space-efficient arrangement.

The gas provided in the closed inner space may be purified air. By purified air is meant that the presence of dust particles is significantly lower when compared to non-purified air. By that the air is purified, the contamination of the electrodes is reduced.

The gas provided in the closed inner space may have a low humidity, preferably not more than 50 % relative humidity. By decreasing the humidity, the dielectric breakdown voltage of the ionic wind generator is lowered. Thus, the electrodes of the ionic wind generator may be provided with a higher voltage or the space between the electrodes may be decreased, thus decreasing the size of the ionic wind generator.

In one embodiment, the lighting arrangement comprises a light source mounted on an upper side of a light source board. The ionic wind generator may in this embodiment be arranged at a lower side of said light source board. This position is advantageous in that the ionic wind generator is located near both the light source and the light source board, but without shadowing the light emitted by the light source and travelling out from the lighting device.

Moreover, the ionic wind generator may be located between the light source board and a driver of the lighting arrangement. Thus, the ionic wind generator is located near the light source board, the light source and the driver, which are all components generating heat. The ionic wind generator may thereby provide a flow of heat away from all of these components in an optimized manner.

It is noted that the invention relates to all possible combinations of features recited in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing embodiment(s) of the invention.

Figs. 1A and 1B illustrate the principle of ionic wind in different generator configurations.

Fig. 2 is a principle sketch of a conventional prior art incandescent lamp.

Fig. 3 is a principle sketch of a prior art lighting device comprising light emitting diodes as light sources.

Fig. 4 is a principle sketch of an embodiment of the present invention applied on a lighting device comprising light emitting diodes.

Fig. 5 is a principle sketch of another embodiment of the present invention.

Figs. 6A and 6B illustrate an embodiment of an ionic wind generator which may be utilized in the present invention.

DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

The principle of ionic wind, which the present invention is based on, will first be described with reference to figures 1A and 1B.

Ionic wind is generated by use of two electrodes: an emitter 10 and a collector 11. A voltage difference is applied between the emitter 10 and the collector 11, such that an electric field is formed. In the illustrated example, the emitter 10 becomes the anode and the collector 11 becomes the cathode based on the applied voltage direction. It is appreciated that in other configurations, a reversed voltage may be applied. In that case, the emitter 10 becomes the cathode and the collector 11 becomes the anode.

Returning to the configuration of figure 1, the emitter 10 ionizes gas molecules in an ionization zone 12 nearby the emitter 10. For this purpose the emitter 10 is preferably at least partly curved strongly, e.g. by being a thin wire or having a sharp edge or tip, which results in strong electric fields in its immediate vicinity. Electrons are pulled away from the gas molecules by that the emitter 10 is positively charged. Thus, positive ionized molecules 13 are formed. The ionized molecules 13 are attracted to the collector 11 which is negatively charged. When moving towards the collector 11 through a drift zone 16, the ionized molecules 13 push neutral molecules 14 to go along. Hence, a so called ionic wind is formed. The direction of the ionic wind is from the emitter 10 towards (and possibly past) the collector 11, as indicated by the arrow 15.

In a reverse configuration, where a reverse voltage is applied, negative ionized molecules are formed by the emitter. The negative ionized molecules are attracted to the positively charged collector. Consequently, an ionic wind is formed.

The ionic wind generator may take different forms, all known to the skilled person. Figure 1B illustrates the principle of an alternative configuration of an ionic wind generator. Here, the emitter 10 is formed by a thin wire which extends in a direction normal the viewing plane. The collectors 11', being two in this embodiment, are parallel plates. The principle for generation of ionic wind is the same as in the previous and other examples: gas molecules are ionized by the emitter 10 into ionized molecules 13. The ionized molecules 13 are attracted to the collectors 11' and will thus move towards these. On their way, the ionized molecules 13 push neutral molecules 14 along and thus an ionic wind movement is created in the direction from the emitter 10 towards (and possibly past) the collectors 11', as indicated by the arrow 15.

In the example illustrated in figure 1B, the ionic wind is allowed to flow past the collectors 11' and further away. Thus, a fan-similar function is provided. The wind direction may be elected by arranging the ionic wind generator in a particular direction, in similarity to a mechanical fan.

In the generator configuration of figure 1A, the collector 11 may be formed as a net, whereby the generated ionic wind is allowed to flow past the collector 11 and further away.

The examples illustrated in figure 1A and 1B are based on the usage of DC voltage. However, as the skilled person knows, there exist also ionic wind generator configurations which are based on an AC voltage.

A conventional prior art incandescent lamp 20 is illustrated in figure 2. The lamp 20 comprises a base 21 and a light bulb 23. The base 21 of the incandescent lamp 20 provides a mechanical and electrical connection to the socket in which the lamp 20 is mounted. The light bulb 23 is typically made from glass or plastics and may be either clear or frosted.

The lamp 20 further comprises a filament 22 which provides the lighting function. A current flowing through the filament 22 heats it to above 2000°C resulting in the emission of visible light. The vast majority of the electrical energy put into the incandescent lamp 20 is converted into heat in the filament 22. Due to its high operating temperature the filament 22 is well cooled by heat radiation.

The inner space of the light bulb 23 contains an inert gas or is evacuated in order to protect the filament 22 against oxidation.

A prior art lighting device 30 comprising light sources 33 in the form of light emitting diodes (LEDs) is illustrated in figure 3. The light sources 33 are arranged on a printed circuit board (PCB) 34. The board of the PCB 34 may be made of for example FR4 material, metal or ceramics. The light sources 33 and the PCB 34 together form a lighting arrangement. In this embodiment, the lighting arrangement further comprises a driver 35. The driver 35 is an electrical component which may be arranged to provide functionality such as current control (low current control or high current control) or suppression of harmonics or distortions in the mains supply.

The prior art lighting device 30 comprises a light bulb 31 and a base 32 which together form a housing for the lighting device 30. The base 32 may be a screw-type base used with Edison sockets or any other type of bulb base size or standard. The base 32 is provided for inserting the lighting device 30 into a socket and to electrically connect the lighting device 30 to mains power.

The temperature of light sources 33, being LEDs in this embodiment, has to be limited to about 100°C in order to provide an acceptable quality and efficiency of light emission. There is only a small amount of heat radiation at this temperature. Hence, heat has to be removed from the light sources 33 by other means. The lighting device 30 therefore comprises a heat sink 36. The heat sink 36 should be as small as possible in order to achieve a high degree of translucent area of the housing of the lighting device 30. This is in particular interesting when the lighting device 30 is made to resemble an incandescent lamp. However, as is illustrated in figure 3, a substantially sized heat sink 36 is often required in order to sufficiently cool the light sources 33.

The heat sink 36 is provided in the housing and in connection to the lighting arrangement comprising the light sources 33, the PCB 34 and the driver 35. The majority of the produced waste heat is typically generated by the light sources 33, in this case the LEDs, and the rest by the driver 35 and components of the PCB 34. The waste heat is transported to the heat sink from the light sources 33 through the PCB 34 and to the heat sink. In the heat sink, the heat is transported to the ambient air by natural convection. The actual construction of the heat sink 36 is not illustrated here. It is appreciated that the skilled person has knowledge of how to design an appropriate heat sink.

Some of the generated waste heat is also transported by natural convection within an inner space 38 of the housing. This movement of the heat is illustrated by flow arrows 37. These flows will reach a portion of the light bulb 31 in the immediate vicinity of the lighting arrangement resulting in a minor contribution to cooling. Hence, by natural convection, a small part of the waste heat generated by the lighting arrangement flows by an inner surface portion of the light bulb 31. When passing this inner surface portion, heat is transmitted to the ambient air through a portion of the light bulb 31. However, only a small portion of the inner surface of the light bulb 31 is utilized since the natural convection force is relatively weak.

It has been realized by the inventors that there is an unexplored potential of heat dissipation through the housing of the lighting device. For this purpose, a lighting device 40 is provided as illustrated in figure 4. The lighting device 40 comprises an ionic wind generator 49 which is configured to provide a flow of gas directed along an inner surface of a housing 41, in this case an inner surface of a light bulb, the light bulb forming a part of the housing 41. By providing a flow of gas is meant that the ionic wind generator blows the gas present within the housing 41 such that the gas is forced in a direction. The direction of flow is given by the configuration of the ionic wind generator 49, i.e. how the electrodes of the generator 49 are arranged in relation to the housing 41. As realized by the skilled person, the exact arrangement depends on the design of the ionic wind generator. Different designs are possible as exemplified in figures 1A and 1B. The ionic wind generator 49 is in this embodiment powered by the driver 35, preferably with high voltage DC.

The ionic wind generator 49 provides a flow of gas directed along an inner surface of the housing 41, as indicated by the flow arrow 47. A higher degree of circulation of gas will be achieved within an inner space 48 of the housing 41 when compared to natural convection. The circulation of gas results in efficient transfer of heat by forced convection from the PCB 34, the light sources 33 and the driver 35 along the inner surface of the housing 41. Heat will be transferred from the circulated gas flowing along the inner surface of the housing 41 by conduction through the housing 41 to the large outer surface of the housing 41. Heat transfer is improved by using a thin wall for the housing 41. However, the thickness has a lower limit coming from mechanical considerations.

Heat is transferred from the outer surface of the housing 41 to the ambient air by natural convection. The heat transfer will be efficient due to the large surface area of the housing 41. Altogether this will result in efficient cooling of the lighting device 40.

Waste heat from the lighting arrangement is still conducted from the lighting arrangement to the heat sink 46. However, one consequence of the increased heat dissipation is that the heat sink 46 of the lighting device 40 may be decreased, which is the case in the embodiment of figure 4. A smaller heat sink 46 enables a larger housing 41 without the need for increasing the outer dimensions of the lighting device 40. Thus, a larger light emitting area for the lighting device 40 may be achieved. Under the condition that the heat dissipation of the housing 41 provides sufficiently cooling in itself, the heat sink 46 may be omitted in total.

Alternatively, the increased heat dissipating capacity may be exploited by increasing the effect of the lighting arrangement, and in particular the light sources 33, without the need for increasing the heat sink.

In this embodiment, the ionic wind generator 49 is located between a PCB 34 and a driver 35. This positioning of the ionic wind generator 49 provides optimal flow pattern, without shadowing the light travelling from the light sources 33, in this embodiment comprising LEDs, to the housing 41 and out from the lighting device 40. The position is advantageous also in that the ionic wind generator is located near both the PCB 34 with the light sources 33 and the driver 35, which are the components generating heat. Thus, the ionic wind generator provides a flow of heat away from all of these components.

The inner space of the housing 41 in figure 4 is closed. This means that the flow of gas is circulated by means of the ionic wind generator in a closed space without the escape or addition of gas. Several advantages are gained by this feature. Firstly, essentially no ozone, which is produced by the ionic wind generator, will leave the closed inner space, so the problem of ozone contamination of the ambient air is not present. Secondly, contamination of electrodes due to oxidation will be negligible in a closed space. Oxidation of the electrodes will either be small or can be controlled to a sufficiently small value via the composition of the gas provided in the inner space of the housing.

The gas provided in the closed inner space 48 may be air. Air is mainly composed of nitrogen (78%), oxygen (21%), and argon (0.93%). Other gases, such as nitrogen or argon, preferably pure, may also be used. One advantage with such gases is that they are free from oxygen which oxidizes the electrodes. However, as stated above, the oxidation is very limited even with oxygen present in the gas, being e.g. air, due to the inner space being closed.

In one embodiment, purified air is provided in the closed inner space. By purified air is meant that the presence of dust particles is significantly lower when compared to non-purified air. By that the air is purified, the contamination of the electrodes is reduced.

In one embodiment, the gas provided in the inner space has a low humidity, preferably not more than 50 % relative humidity. The relative humidity is defined as the ratio of the partial pressure of water vapor in an air-water mixture to the saturated vapor pressure of water at a prescribed temperature. The relative humidity of air depends on temperature and pressure. By decreasing the humidity, the dielectric breakdown voltage of the ionic wind generator is lowered. Thus, the electrodes of the ionic wind generator may be provided with a higher voltage or the space between the electrodes may be decreased, thus decreasing the size of the ionic wind generator.

Moreover, electronics are usually designed for operation in the range of 30 to 50 percent, since this is the healthy humidity range for humans. Thus, it is preferred that the gas provided in the inner space has a humidity in the range of 30–50 %, which may be beneficial for both the ionic wind generator and other electronics provided within the housing.

The embodiments illustrated in figures 3 and 4 are so called LED retrofit lighting devices (also called retrofit lamps). These lamps are designed to be direct replacements of incandescent lamps. However, it is appreciated that other types of lighting devices having different shapes are possible within the scope of the invention. For example, the present invention may be applied to lighting devices such as spot lights, light tubes, downlight lighting devices or floodlights (lighting devices providing even illumination across a wide area).

Moreover, the light source of the lighting device is not limited to being necessarily one or more LEDs. Non-limiting examples of possible light sources are organic light emitting diodes (OLEDs) and diode lasers.

A specific embodiment of how to integrate an ionic wind generator 59 is illustrated in figure 5. The lighting device 50 is otherwise configured similar to the lighting device 40 in figure 4.

The ionic wind generator 59 utilizes the principle of the ionic wind generator in figure 1B. Here, the collector plates 51, 52 are grounded and the emitter 53 is positively or negatively charged, thus creating the required electric field. In this embodiment, the collector plate 52 is merged with a ground plane in the PCB 34. Alternatively, or in addition, the collector plate 51 may be merged with a ground plane in the driver 35. Thus, the ionic wind generator becomes integrated, partly or in full, with the lighting arrangement, thereby providing a space-efficient arrangement.

Figures 6A and 6B illustrate yet another alternative design of an ionic wind generator 69 for use in a lighting device according to the present invention. Figure 6A is a perspective view from above the PCB 34 and figure 6B is a view from below of the PCB 34.

An emitter 60 is formed as a comb with high voltage tips 63 arranged on a common base 62. A collector 61 is formed as a grounded plane which may be partly or fully integrated in a ground plane of the PCB 34, or alternatively in a ground plane of the driver 35 or other component. An ionic wind is generated by the electrodes, according to the same principle as previously disclosed, with a direction indicated by 15. Light sources 33, in the form of LEDs, are positioned at a location on the PCB 34 above the grounded collector 61. This positioning is advantageous in that the light sources 33 are protected from the electric field, potentially being high, formed between the positively or negatively charged emitter 60 and the grounded collector 61.

As exemplified above, ionic wind generators utilized in the present invention may take various forms and be more or less integrated into the lighting arrangement.

It should be noted that it is preferred that the ionic wind generator utilizes DC voltage, since this can be made more easily at present. However, it is by no means excluded that ionic wind generators utilizing AC voltage may be used in a lighting device according to the present invention.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. For example, alternative light sources such as OLEDs and diode lasers may be utilized.

Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person 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.

CLAIMS:

1. A lighting device comprising:

– a housing (41);

– a lighting arrangement located in an inner space (48) of said housing (41), wherein the lighting arrangement comprises a light source (33) mounted on an upper side of a light source board (34); and

– an ionic wind generator (49, 59, 69) arranged in said inner space (48), wherein the ionic wind generator (49, 59, 69) is arranged at a lower side of said light source board (34),

characterized in that:

the inner space (48) is closed; and

the ionic wind generator (49, 59, 69) is configured to provide a flow of gas directed along an inner surface of said housing (41).

2. The lighting device according to claim 1, wherein the housing (41) comprises a translucent portion of a heat conducting material and wherein the ionic wind generator (49, 59, 69) is arranged to direct the flow of gas along said translucent portion.

3. The lighting device according to claim 2, wherein the translucent portion is bulb shaped.

4. The lighting device according to any of claims 1–3, wherein the ionic wind generator (59) comprises a grounded collector (51, 52) and an emitter (53) provided with a positive or negative voltage in relation to the collector (51, 52), the grounded collector (51, 52) being formed by a grounded portion of the lighting arrangement.

5. The lighting device according to any one of claims 1-4, wherein the gas provided in the inner space (48) is purified air.

6. The lighting device according to any one of claims 1-5, wherein the gas provided in the inner space (48) has a low humidity, preferably not more than 50 % relative humidity.

7. The lighting device according to any of claims 1–6, wherein the lighting arrangement further comprises a light source driver (35).

8. The lighting device according to any of claims 1–7, wherein the lighting arrangement comprises a light source (33) in the form of a light emitting diode.

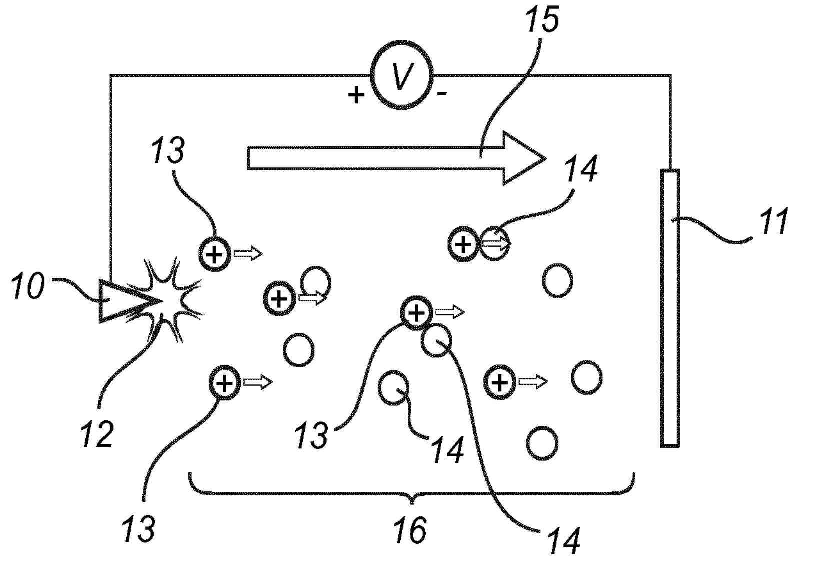


Fig. 1A

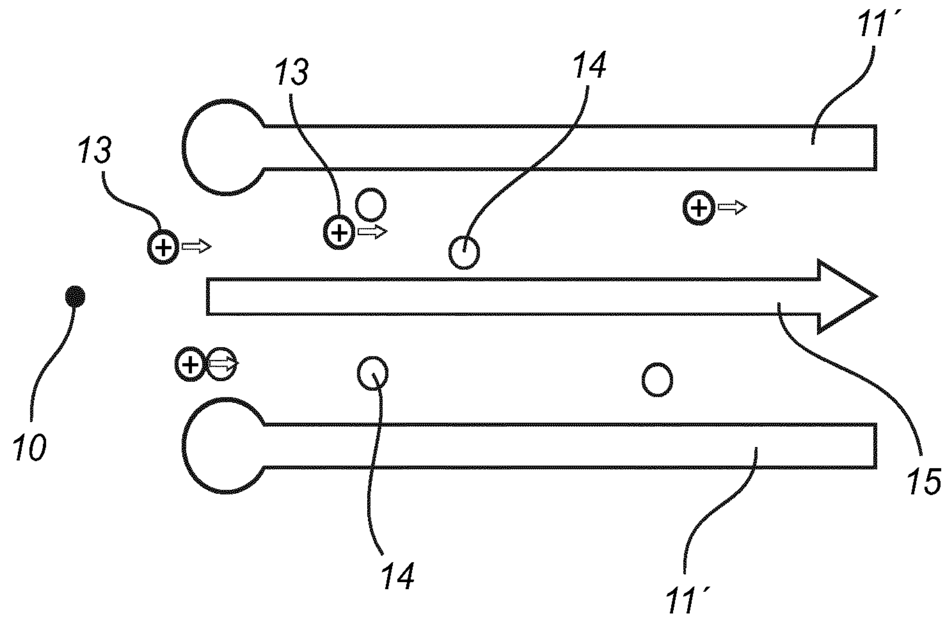
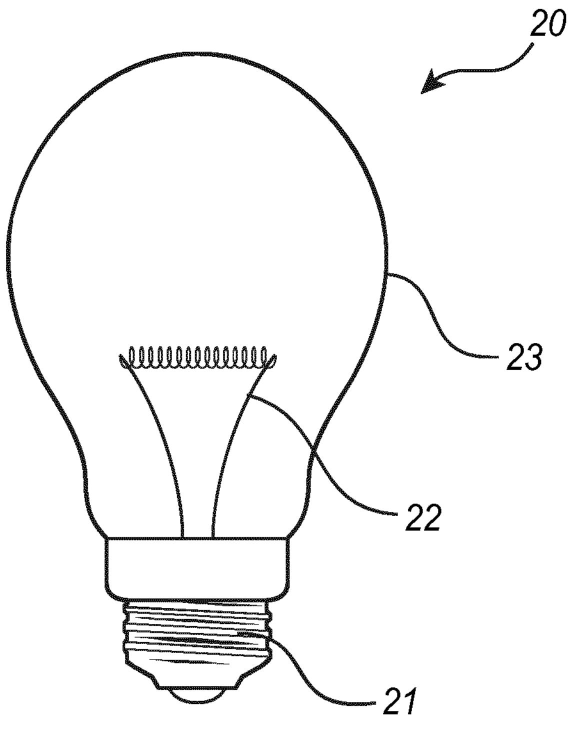
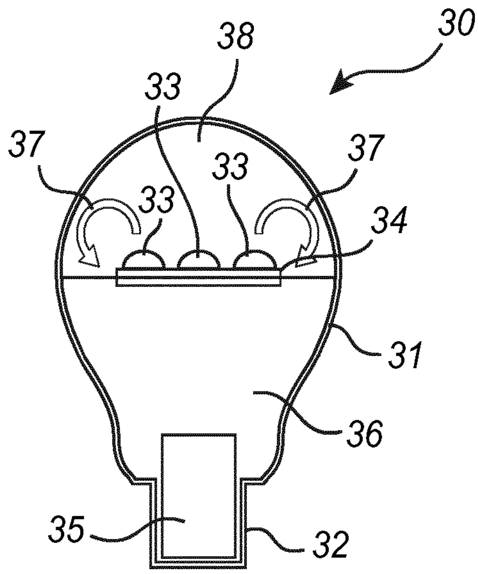


Fig. 1B



(Prior art) Fig. 2



(Prior art) Fig. 3

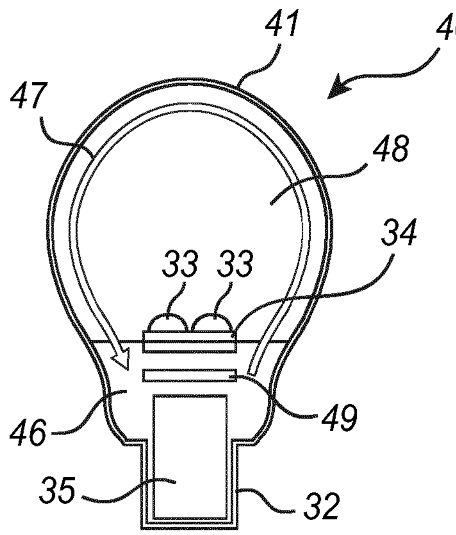


Fig. 4

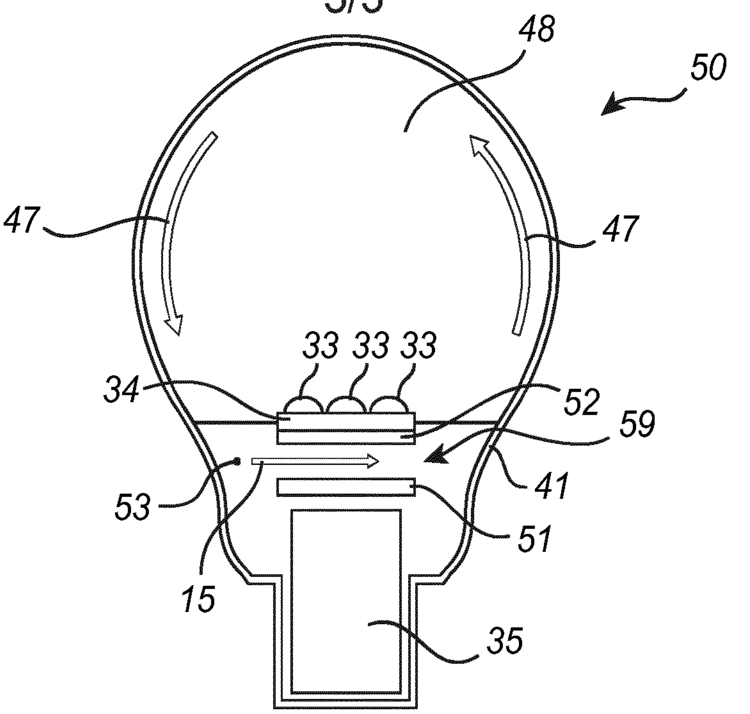


Fig. 5

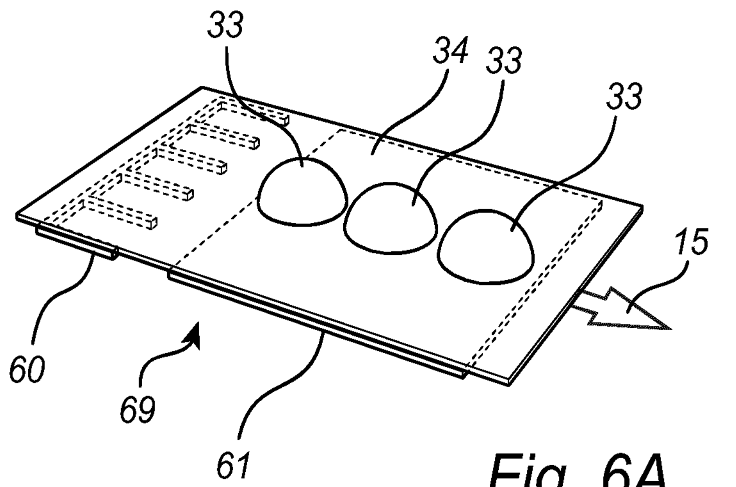


Fig. 6A

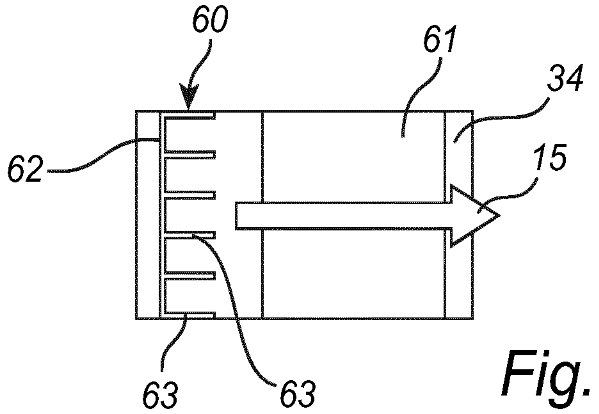


Fig. 6B

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/050827

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21V29/02 F21V29/00 H01T23/00
ADD. F21K99/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21V F21K H01T

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/271989 A1 (HUSSELL CHRISTOPHER P [US] ET AL) 17 October 2013 (2013-10-17) paragraph [0112]; figure 17	1-8
A	US 2011/148321 A1 (KWON SEONG HUN [KR] ET AL) 23 June 2011 (2011-06-23) paragraph [0040] - paragraph [0048]; figure 1	1,6-8
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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20 February 2015	27/02/2015

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/050827

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