

GAS COOLED LIGHT EMITTING DIODES

FIELD OF INVENTION

5 The invention relates to gas cooled light emitting diodes (LEDs).

BACKGROUND

Light emitting diode (LED) lighting sources provide light in many settings. LED
10 lighting sources are relatively efficient, long-lasting, cost-effective, and environmentally friendly.

The performance of LED lighting sources largely depends on the ambient temperature of the operating environment. Overloading an LED lighting source in
15 high ambient temperatures can result in overheating which may lead to device failure. Adequate heat dissipation is required to prolong the life span of LED lighting sources.

In particular, the LED has to maintain its diode junction temperature within the
20 rated range to maximize efficiency, longevity, and reliability. Constant operation at high junction temperatures can result in less light output and a shorter life span. Most LEDs manufacturers claim their light output and other performance data on the basis of the junction temperature of 25°C. These performance data are derived from tests that are done within micro seconds after lighting up. Light output decreases as
25 operation time increases and temperature increases.

An important design aspect of LED lighting is towards heat dissipation. Currently, the most common method of heat dissipation involves the use of heat sinks that are usually made of metals with good thermal conductivity characteristics.
30 Heat is dissipated by means of surface contact between the LED array and the heat sink. However, cooling by heat sinks may not keep the junction temperature of LEDs close to the rated 25 °C for the claimed life span of 100,000 hours. This is because the rate of heat dissipation does not correspond with the rate of temperature rise of the LED (e.g. during a surge in supply voltage). When dust is collected and trapped
35 in between the heat sinks' fins, the heat transfer rate deteriorates further, affecting the light output and lifespan of the LED.

LEDs can also be cooled by liquids. The liquids conduct heat away from the semiconductor junction to the surface of the LED enclosure by convection. Subsequently, the heat at the surface of the enclosure can be dissipated by radiation. However, the inherent viscosity and specific heat capacity of liquids cause delays in
5 establishing a convection current that is able to dissipate heat effectively. Further, the heated liquids may release occluded gases, hindering effective convection.

A need therefore exists to provide a gas cooled light emitting diode (LED) that seeks to address at least one of the abovementioned problems.

SUMMARY

According to an aspect of the present invention, there is provided a light emitting diode (LED) lighting source, comprising: an LED source; and an enclosure
15 surrounding the LED source; wherein a gas or gas mixture is filled within the enclosure such that the gas or gas mixture acts as a medium for heat transfer away from the LED source; and wherein the gas or gas mixture is chosen to provide an increased heat transfer from the LED source compared to air.

20 The heat may be transferred from the LED source to the surface of the enclosure by convection current.

The material of the enclosure may be chosen to facilitate the transmission of light and the transfer of heat from the surface of the enclosure to the ambient
25 surroundings by radiation.

The surface of the enclosure may comprise glass.

The gas or gas mixture may have a combined molecular weight of less than
30 5.3.

The gas or gas mixture may have a combined thermal conductivity of more than 0.14 W/g/°C.

35 The enclosure may facilitate the funneling of the gas or gas mixture towards the LED source.

The LED source may comprise a LED semiconductor structure.

The LED lighting source may further comprise an electrical connection from the LED lighting source to the mains supply.

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The LED lighting source may further comprise a stem for mounting the LED source within the enclosure.

The gas may comprise Hydrogen and the gas mixture may comprise Nitrogen and Helium.

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BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

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Figure 1 is a schematic diagram illustrating the structure of an LED light source, according to an embodiment of the present invention.

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Figure 2 is a schematic illustrating the formation of convection currents within an enclosure of an LED light source, according to an embodiment of the present invention.

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Figure 3 is a schematic illustrating the temperature distribution within an LED light source, according to an embodiment of the present invention.

DETAILED DESCRIPTION

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Embodiments of the present invention seek to cool light emitting diode (LED) lighting sources so as to promote higher energy efficiency, longer life span and therefore provide cost benefits. Consequently, disadvantages associated with solid heat sinks and liquid cooling systems can be avoided.

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In an example embodiment of the present invention, an LED source, here in the form of an LED semiconductor structure, is placed in an air-tight enclosure. The air-tight enclosure is filled with a pure gas or a mixture of gases. The gas or mixture of gases act as a medium to transfer heat from the LED source to the surface of the enclosure by gaseous convection. Heat from the surface of the enclosure is subsequently dissipated through radiation or convection with the ambient air.

Pure non-reactive (inert) gases or mixtures of non-reactive gases are preferred for cooling LEDs. The gas or gas mixture is preferably non-corrosive and does not react with the LED and the components within the enclosure. Further, the gas or gas mixture is preferably stable under heat and electric flow. Reactive and corrosive gases such as Oxygen, Halogens, Freons, Hydrocarbons and Refrigerants are not suitable for cooling LEDs.

Gases have relatively low molecular weights and are very mobile (compared to solids or liquids). For example, Hydrogen molecules move at a speed of 1840 m/s at 0 °C and 1930 m/s at 100 °C. Gases with relatively heavier molecular weights are more sluggish compared with lighter ones. For example, the relatively heavier molecules of Air move at a slower speed of 484.3 m/s. Thus, Hydrogen molecules move about 4 times faster than Air molecules even without convection. Accordingly, gases with low molecular weights can carry away / transfer and dissipate heat relatively faster than solids and liquids and therefore gases are preferred in example embodiments. More preferably, the gas or gas mixture is chosen to have a molecular weight less than 5.3.

In an example embodiment, a gas mixture comprises 95% of He (molecular weight of 4.02) and 5% of N₂ (molecular weight of 28.03). Accordingly, the molecular weight of the gas mixture is $[(0.95 \times 4.02) + (0.05 \times 28.03)] = 5.221$

In another example, the gas comprises 100% of H₂ (molecular weight of 2.01).

This is in contrast to conventional light bulbs, wherein the bulb is filled with a gas/gas mixture having a relatively larger molecular weight (e.g. argon) so as to minimize conduction and convection losses within the bulb and to reduce tungsten filament vaporization.

Gas	Formula	Molecular weight	Specific gravity (g/l) at STP	Thermal conductivity (k) (W/g/°C)	Cv=Specific Heat Constant Volume at
Helium	He	4.02	0.176	0.1513	0.7463
Neon	Ne	20.18	0.899	0.0491	0.1487
Argon	Ar	39.95	1.782	0.01772	0.0250
Krypton	Kr	83.80	3.75	0.00943	0.0119
Xenon	Xe	131.01	5.761	0.00565	0.0229
Radon	Rn	222.00	9.730	0.00361	0.0135
Hydrogen	H ₂	2.01	0.088	0.1805	2.4876
Nitrogen	N ₂	28.03	1.165	0.02583	0.1783
Air	-	28.97	1.293	0.02574	

Table 1

N.B.: STP = Standard Temperature & Pressure, Standard Temperature = 300°K
Standard Pressure = 14.7psi = 760mmHg

- 5 With reference to Table 1 above, the thermal conductivity (k) of Hydrogen is about 10 times more than Argon and about 7 times more than Nitrogen and Air. Accordingly, the use of gases with a relatively higher thermal conductivity is preferred in example embodiments. The gas or gas mixture is preferably chosen to have a thermal conductivity larger than that of air. More preferably, the gas or gas mixture is
- 10 chosen to have a thermal conductivity larger than 0.14 W/g/°C.

In an example embodiment, a gas mixture comprising 95% of He and 5% of N₂ has a combined thermal conductivity of $[(0.95 \times 0.1513) + (0.05 \times 0.02583)] = 0.145 \text{ W/g/°C}$.

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In another example, a gas comprising 100% of H₂ has a thermal conductivity of 0.1805 W/g/°C.

- 20 In an example embodiment of the present invention, by using Hydrogen for cooling, it is possible to cool LEDs 7 times (4 times more mobile supporting conductivity and 7 times higher thermal conductivity) faster than cooling by Air with the heat sinks.

- 25 The type of gas or gas mixture used for cooling, their constituent ratios and proportions (for a gas mixture), and the pressure in which they are contained within the enclosure depend on the wattage, envelope, shape and mass of the LED. In embodiments of the present invention, for a fixed enclosure size, as the wattage

increases, the gas/gas mixture is chosen such that it has a higher thermal conductivity.

The amount of gas can be calculated from the following:

5 Sp. Gravity = gms/litre

Mass of gas inside the bulb volume of 0.12 litre at $T=300^{\circ}\text{K}$ at Atmospheric pressure of 14.7psi = Sp. Gravity $\times$ 0.12gms.

10 Example 1 : 95% He and 5% N_2

P:14.7psi

V:0.12litre

T:300°K

15 Mass inside bulb= $[(0.95 \times 0.176) + (0.05 \times 1.165) = 0.2255] \times 0.12\text{gms} = 0.02706\text{gms}$

Example 2 : 100% H_2

P:14.7psi

V:0.12litre

20 T:300°K

Mass inside bulb= $0.088 \times 0.12\text{gms} = 0.01056\text{gms}$

As the LED is operated, due to heat generated, the temperature rises from T_1 (ambient temperature) to T_2 .

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The heat generated, in calories per second, can be calculated using the formula:

$$H = m \cdot s \cdot t \quad - \quad (3)$$

30 where m = mass of the LED semiconductor.

s = specific heat of the LED semiconductor.

$t = (T_2 - T_1)$, the increase in temperature (in Kelvin)

35 The heat generated, in Joules per second (Watts), can be calculated using the formula:

$$H' = 4.2(m \cdot s \cdot t) \text{ watts} \quad - \quad (4)$$

For cooling gas = $4.2m' \cdot C_v \cdot t$ watts

$$= 4.2 \times 0.01056 \times 5/2.01 \times 100$$

= 11.03 watts is the cooling capacity of hydrogen gas inside a 60mm glass bulb.

5 The heat generated must be dissipated by the gas or gas mixture filled within the enclosure. Due to the nature of the chosen gas or gas mixture, cooling is rapid by convection current. The flow of the convection current within the enclosure is guided by the physical shape of the enclosure.

10 Figure 1 is a schematic diagram, generally designated as reference numeral 100, illustrating the structure of an LED light source, according to an embodiment of the present invention. The LED light source 100 comprises an enclosure 102, a base 104, an LED semiconductor 106, a driver/regulator 108 and a stem 110. The stem comprises 2 leads 110a and 110b (e.g. positive and negative leads; or AC leads)
 15 extending from an air-tight sealed-in-glass portion 111 and the stem 110 functions to mount the LED semiconductor 106 within the enclosure 102. The driver/regulator 108 can be a passive component such as a metal film resistor. The base 104 shown here is an Edison screw base. However, it will be appreciated by a person skilled in the art that other suitable bases, e.g. bayonet base, bipin can be used. The driver 108
 20 comprises suitable circuitry to enable the appropriate voltage and current to be supplied to the LED semiconductor 106. It will also be appreciated by a person skilled in the art that other conventional components, e.g.: a ballast (not shown), can be included in the LED light source. Figure 1 shows a single LED semiconductor 106. However, more than one LED semiconductor (i.e.: an array of LED semiconductors)
 25 can be used.

 Figure 2 is a schematic, generally designated as reference numeral 200, illustrating the formation of a convection current within an enclosure of an LED lighting source, according to an embodiment of the present invention. Convection
 30 currents 202, 204 and 206 are set-up with the enclosure and provide means for heat dissipation away from the LED semiconductor to the surface of the enclosure. The flow of the convection currents 202, 204 and 206 are laminar to facilitate efficient heat transfer. The shape of the enclosure is chosen such that it facilitates the funneling of the gas or gas mixture within the enclosure towards the junction of the
 35 LED. Heat from the surface of the enclosure is subsequently dissipated through radiation or convection with the ambient air. Accordingly, the material of the enclosure is preferably chosen to facilitate the transmission of light and the transfer

of heat from the surface of the enclosure to the ambient surroundings by radiation. An example of such a suitable material is glass.

In an example embodiment of the present invention, the shape of the enclosure is in the form of a General Lighting Service (GLS) lamp, in particular, the conventional 60 mm diameter pear-shaped glass bulb. By using an existing bulb shape for the enclosure, existing 25W, 40W, 60W and 100W Tungsten Filament Lamps can be directly replaced with about 4W, 8W, 12W and 20W LED lighting sources according to embodiments of the present invention. No change in electrical wiring or design may be necessary as the same supply voltage sockets are used. The surface of the bulb can be made of clear glass, soft coated, diffused coated or coated with a reflective material for suitable/desirable lighting designs.

Figure 3 is a schematic, generally designated as reference numeral 300, illustrating the temperature distribution within an LED light source, according to an embodiment of the present invention. The LED light source is rated at 230V AC, 0.020A and 4.60W and the temperature distribution during continuous operation (i.e.: at steady state) is shown. Around the areas denoted by reference numerals 302, 304 and 306, the temperature is about 60°C, 50°C and 40°C respectively.

In embodiments of the present invention, a proper selection of the constituent gases for heat dissipation, its quantity (and therefore pressure, assuming a fixed enclosure shape) and the shape of the enclosure and the bulb surface finish advantageously enable the operation of LEDs around their safe junction temperature.

Embodiments of the present invention advantageously enable relatively faster heat dissipation compared to metallic heat sinks. An increase in power output without a substantial increase in operating temperature may be achieved. In other words, an increase in light output may be achieved with no additional input power. Increased light output for the same input power, i.e. an increase in Lumens per Watt (LPW), means that recurring cost is lower as less energy is required. Embodiments of the present invention can also prolong the life span of LED light sources.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the embodiments without departing from a spirit or scope of the invention as broadly

described. The embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A light emitting diode (LED) lighting source, comprising:
an LED source; and
5 an enclosure surrounding the LED source;
wherein a gas or gas mixture is filled within the enclosure such that the gas or
gas mixture acts as a medium for heat transfer away from the LED source; and
wherein the gas or gas mixture is chosen to provide an increased heat transfer from
the LED source compared to air.
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2. The LED lighting source as claimed in claim 1, wherein the heat is transferred
from the LED source to the surface of the enclosure by convection current.
3. The LED lighting source as claimed in claim 1 or 2, wherein the material of
15 the enclosure is chosen to facilitate the transmission of light and the transfer of heat
from the surface of the enclosure to the ambient surroundings by radiation.
4. The LED lighting source as claimed in any of the preceding claims, wherein
the surface of the enclosure comprises glass.
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5. The LED lighting source as claimed in any of the preceding claims, wherein
the gas or gas mixture has a combined molecular weight of less than 5.3.
6. The LED lighting source as claimed in any of the preceding claims, wherein
25 the gas or gas mixture has a combined thermal conductivity of more than 0.14
W/g/°C.
7. The LED lighting source as claimed in any of the preceding claims, wherein
the enclosure facilitates the funneling of the gas or gas mixture towards the LED
30 source.
8. The LED lighting source as claimed in any of the preceding claims, wherein
the LED source comprises a LED semiconductor structure.
- 35 9. The LED lighting source as claimed in any of the preceding claims, further
comprising an electrical connection from the LED lighting source to the mains supply.

10. The LED lighting source as claimed in any of the preceding claims, further comprising a stem for mounting the LED source within the enclosure.

11. The LED lighting source as claimed in any of the preceding claims, wherein
5 the gas comprises Hydrogen.

12. The LED lighting source as claimed in any of the preceding claims, wherein the gas mixture comprises Nitrogen and Helium.

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