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HIGH POWER LED FISH COLLECTOR HEAT SINK

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МОЩНЫЙ СВЕТОДИОДНЫЙ РАДИАТОР ДЛЯ СБОРА РЫБЫ

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Abstract. High-power LED fish collector lamps are small in size and work with high heat flow density, LED chips emit more and more heat, and heat dissipation problems have gradually become a bottleneck limiting the development of LED. In this paper, for a typical power LED, it mainly discusses the LED packaging technology, the heat sink structure and characteristics of the impact on the heat dissipation conditions.

Аннотация. Мощные светодиодные лампы для сбора рыбы имеют небольшие размеры и работают с высокой плотностью теплового потока, светодиодные чипы излучают все больше и больше тепла, а проблемы с отводом тепла постепенно стали узким местом, ограничивающим развитие светодиодов. В этой статье для типичного мощного светодиода в основном обсуждаются технология упаковки светодиодов, структура радиатора и характеристики влияния на условия рассеивания тепла.

Keywords: high power LEDs; packaging technology; heat dissipation; thermally conductive plastics.

Ключевые слова: светодиоды большой мощности; технология упаковки; рассеивание тепла; теплопроводные пластмассы.

1. Introduction

LEDs are known as the fourth generation of new light sources, with high energy efficiency and superb life span. Fish catching lights are an indispensable aid to fishing operations as they are used to improve the yield of the catch through the collection of light by using the photophobic properties of fish. Fish catching lamps have undergone a transformation from paraffin, incandescent, gold tungsten and metal halide lamps to LED lamps [1]. They can be divided into two categories: above-water lights and underwater lights, of which underwater fish-collecting lights have the characteristics of energy saving, wide range of trapping and deep penetration of water layers [2]. In the late 1990s, fish collection lights were gradually applied to marine light trap fisheries. Foreign countries have invested huge energy and material resources in research and development of LED fish collection lights (above-water and underwater lights), and practice has shown that the energy-saving effect of LED lights is remarkable. Japanese experiments have shown that the use of LED fish collection lights on squid fishing boats can save fuel costs by about 70% [3]; the use of LED lights on fishing boats with raft nets can save fuel costs by more than 30% [4].

However, in practical applications, high-power LED lights can only convert 15% of the input power into light energy, while the remaining 85% can only be converted into heat energy. If the energy of the chip is not dissipated in time, the life of the LED will be shortened, so the problem of heat dissipation is one of the bottlenecks affecting the development of high-power LEDs. Therefore, it is of great practical importance to analyse and optimise the heat dissipation of LED lamps.

2 Packaging technology

2.1 LED package structure

Looking at the industry chain of high power LEDs, packaging is an essential step from LED chips to applications. Packaging not only ensures better performance of LED devices by improving reliability and optical characteristics, but also enables control and tuning of the final optical performance. There are two ways to build LED arrays, as shown in Figure 2.1.The first one is to mount surface mount (SMT) HP-LED packages on a substrate, and the second one is to arrange LED chips directly on the substrate, called chip-on-board (COB) arrays [5]. Compared with SMT LED arrays, COB arrays offer advantages such as cost efficiency with reduced number of assembly parts and manufacturing processes, high package density, high-precision chip placement, color mixing, and low junction temperature. This has led more relevant researchers to focus on improving their limitations in the lighting market.

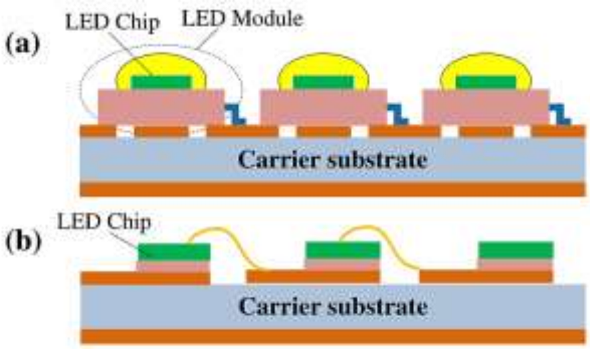

Figure 2-1. Two different types of LED array:(a) SMT; (b) COB

2.2 Influence of junction temperature

During normal operation of an LED chip, the heat generated by the chip raises the temperature of the PN junction. For LEDs, the chip junction temperature Tj refers to the temperature of the PN junction. The junction temperature is one of the most important parameters of an LED chip and will directly affect the luminous efficiency, reliability, effective life, phosphor efficiency and color temperature of the LED. Therefore, it can be considered that the junction temperature is the most intuitive criterion to measure the working condition of the LED.

For LED packaging structure, In a constant heat flow density state, the junction temperature of the LED chip rises, and fter a certain period of time to reach a stable thermal equilibrium, the light and color performance of the LED can only be established when the junction temperature reaches thermal equilibrium. Normal operation of the LED generally requires the junction temperature below 110°C, if the package heat dissipation is poor, it will make the chip temperature rise, causing uneven stress, reduce luminous efficiency, phosphor conversion efficiency decline. At the same time, the junction temperature of the LED will cause the temperature of the epoxy glue to rise as well. The epoxy resin usually used in the package is not resistant to high temperatures. When the epoxy is at a higher temperature (even if it does not exceed the transition temperature Tg), the encapsulated epoxy (especially in the vicinity of the chip) will gradually degrade and yellow, affecting the light transmission performance of the encapsulated epoxy. This is a subtle process, and the LED surface will gradually lose its luster as the working time increases. Finally, the rise in LED junction temperature can have a serious impact on the effective life of the LED. According to Arrhenius' law, for every 10°C reduction in chip temperature, twice the effective life span. The relationship between light failure and junction temperature published by Cree in Figure 2-2 shows that if the junction temperature is at 65°C for a long period of time, then its light failure to 70% can be as high as 100,000 hours, while when the junction temperature is at 105°C for a long period of time, its life is only 10,000 hours [6].

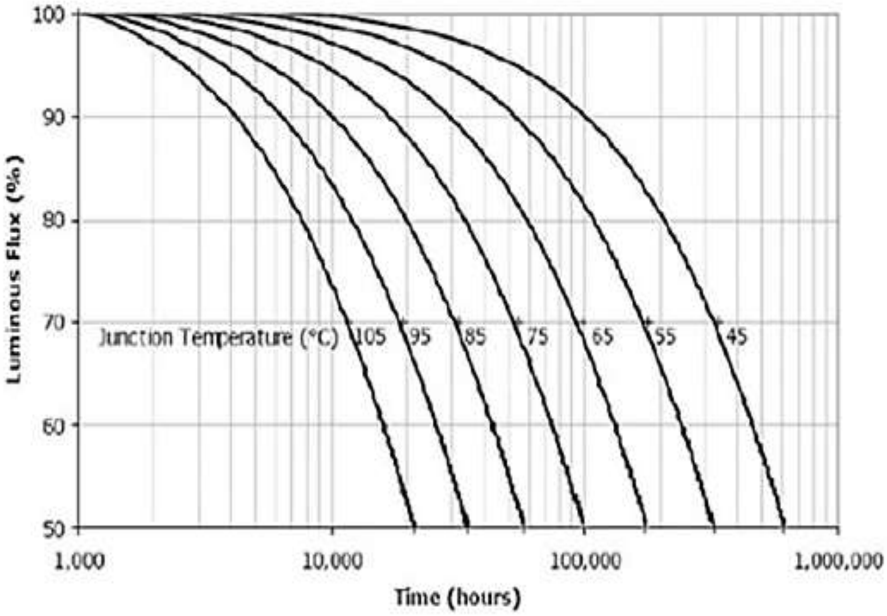

Figure 2-2. Variation LED junction temperature and lifetime

2.3 Submount material

For high-power LED packaging, thermal conductivity is a key factor . The literature on submount materials shows Si [7-9] and AlN [10-11] are most common materials are used as submount. The remarkable properties of these materials, such as coefficient of thermal expansion, thermal conductivity and price allow them to be used in different scenarios.

Most of large LED-suppliers produce single chip package, parts of that as surface mount devices(SMDs) so that they can be treated automatically during further processing. The main drawback for single chip packages is overall size that does not allow high package densities and restricts the radiant flux output per unit area. Typical values for the packing density can be as low as 1-5%.

On Figure2-3. We see two different single chip high-power package. There are the following interface: Chip-heat sink slug, heat sink slug-PCB and PCB-heat sink.

2.4 Power Packaging Technology and Development Trend

At present, there are two types of power LED packaging technology: manual packaging means that each packaging process is carried out by hand and is mainly suitable for prototypes and small batch production. The protection level of the LED underwater fish collection light is IP68, which requires complete waterproofing and can be used for a long time under certain pressure of water. The LEDs are small and flexible, and can be installed in the form of points, lines and surfaces [12].

LED packaging involves several disciplines (e.g. optics, thermal, mechanical, electrical, mechanical, materials, semiconductors, etc.). While the choice of materials (thermal substrates, phosphors, potting adhesives) is important, the packaging structure (e.g. thermal interface, optical interface) also has a significant impact on LED light efficiency and reliability. The packaging technology of high-power LEDs should mainly meet the following two requirements: first, the packaging structure should have high light extraction efficiency; second, the thermal resistance is as low as possible, so as to ensure the optoelectronic performance and reliability of high-power LEDs [13].

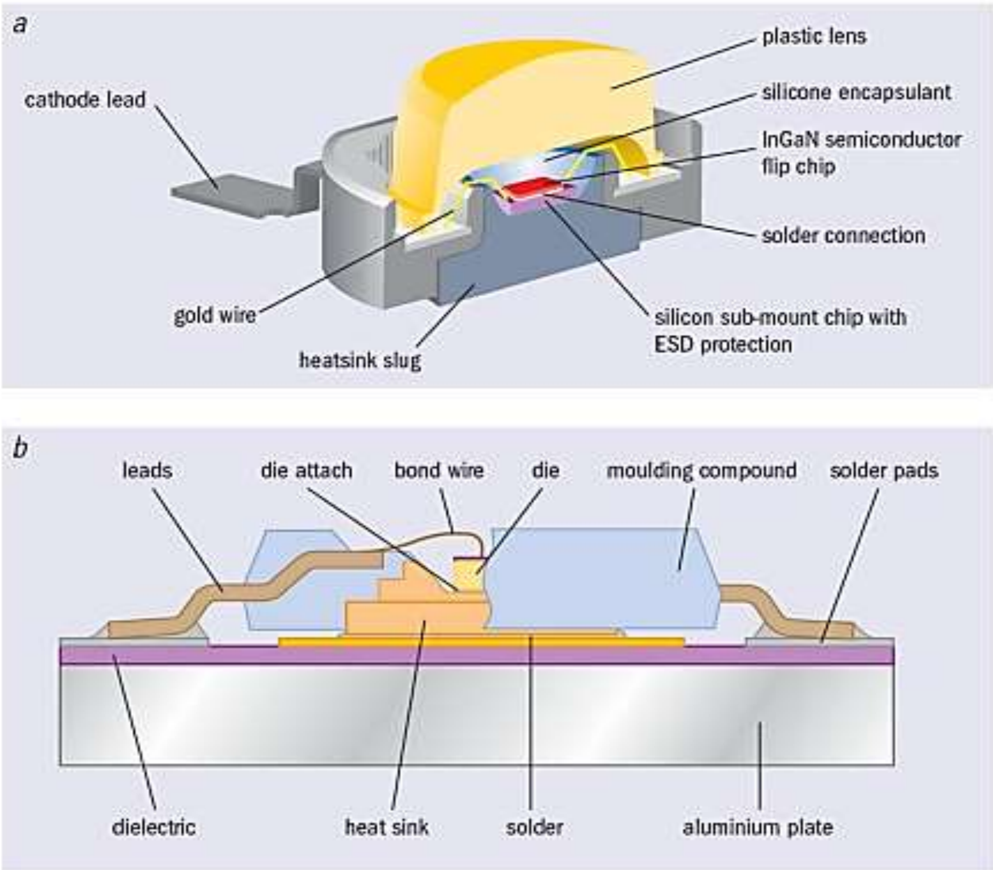

Figure 2-3. (a) SMT-LED (b) SMT-LED on MCPCB

To meet these requirements, especially in the production process of high-power devices, many experts in China have proposed some improvements, such as abandoning some epoxy materials and using some more stable materials, such as glass, PC, etc., to make the lens; you can let the epoxy does not directly contact the chip surface, filled with a gel-like transparent silica gel with stable performance in the middle; using LED film integrated package structure instead of PCB structure, etc. [14]. The future development trend can be developed in various directions, such as the use of large-area chip packaging, chip flip technology, metal bonding technology, the development of new phosphor and coating process, the development of new packaging materials, multi-chip integrated packaging, etc.

3 Radiator

3.1 Analysis of heat dissipation factors

The main function of the heat sink is to continuously dissipate the heat generated during the operation of the LED chip into the surrounding environment to ensure that the LED luminaire works properly. The quality of the heat sink depends mainly on the thermal resistance of the heat sink. The smaller the thermal resistance, the better the thermal conductivity and heat dissipation of the heat sink [15]. The total thermal resistance of a heat sink is not only related to its own factors such as the heat sink area, geometry and radiation coefficient of the surface material, but is also influenced by external factors such as the heat producing power of the LED and the convection coefficient of the surrounding environment, which is not a constant value [16].

3.2 Heat sink construction

Figure 3-1 shows a side view of a particular type of LED heat sink on the market.

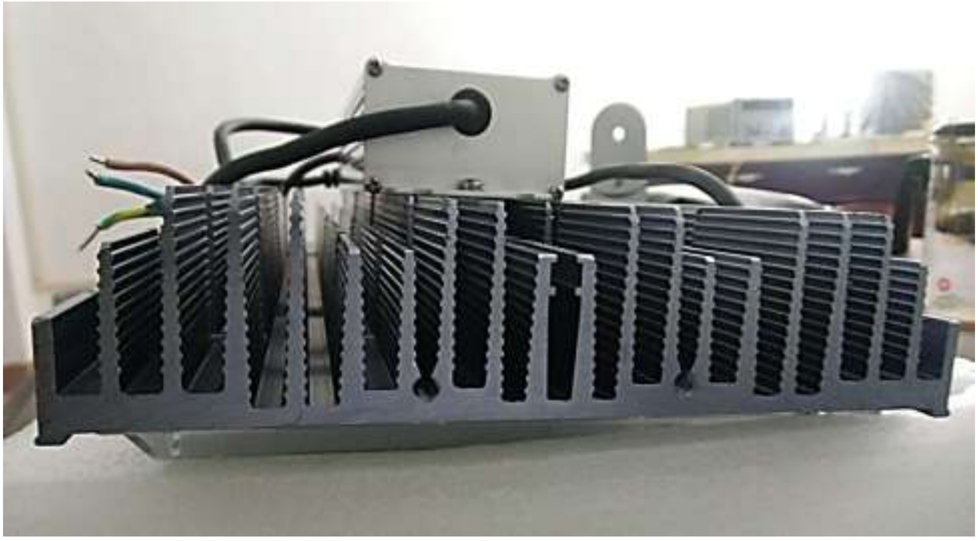

Figure3-1. Fish collection light radiator

(1) Number of radiator fins

The heat sink area is defined as the sum of all surface areas exposed to the surroundings, the larger the heat sink area, the greater its thermal capacity. Underwater fish collection lights work inside seawater, which carries away a large part of the heat. The different fin heights and fin spacing determine the area of the convection surface and are important factors in the heat dissipation effect of the radiator. The higher the number of fins on a radiator, the larger its heat dissipation surface area, so that heat can be dissipated more quickly [17]. On the one hand, increasing the fins increases the convective heat transfer area, which helps to reduce the total area thermal resistance, but the fins increase the solid thermal conductivity resistance . On the other hand, overly dense fins will require higher processing technology. Therefore, the number of fins cannot be increased indefinitely, and the above needs to be taken into account during the actual design and optimisation of the heat sink; based on experience with the machining process, the number of fins generally does not exceed 40 [18].

(2) Analysis of the width of the radiator fins

The change in the thickness of the radiator fins does not have a significant impact on the operating temperature of the lamps, as the increase in fin thickness does not effectively increase the fins' heat dissipation area, but instead causes an increase in the weight of the radiator and raises the cost. Based on the experience of the extrusion process, the thickness of the fins is reduced as much as possible, provided that the thickness of the fins is greater than 1mm.

(3) Analysis of the height of the radiator fins

For the analysis of the fin height, when doing the experiments, we kept the other geometric parameters and environmental conditions constant and obtained a graph of the radiator fin height versus the temperature of the luminaire after simulation with the software. As the fin height increases, the temperature of the luminaire decreases, and the calculation converges when the fin height increases to a specific value or so. Increasing the heat sink fin height can effectively improve the heat sink's cooling capacity, but increasing the fin height excessively will increase the weight of the LED luminaire, and the luminaire temperature will increase instead, which is not in line with the actual application requirements. Experiments have shown that for the designed orthogonal test the influence of each factor on the index, i.e. the chip temperature, is in the following order: fin thickness , fin height , fin spacing ,base plate thickness [19].

3.3 Heat sink materials

The influence of the heat sink material on the heat dissipation effect is reflected in the difference in its thermal conductivity. Qualitatively speaking, the greater the thermal conductivity, the lower the thermal resistance, the greater the ability of the heat sink to conduct heat, and the lower the temperature of the LED chip. Therefore, the material used to make the heat sink must have a certain degree of thermal conductivity, which means that it must have a high thermal conductivity in order to continuously export the heat generated by the chip and eventually dissipate it to the environment; of course, for thermally conductive materials, in addition to thermal conductivity, they should also have a small specific gravity, low price, high strength, easy processing and other characteristics.

In the common metal thermal conductivity materials, aluminium and copper thermal conductivity is relatively high, but the price of copper is high, the ratio is significant, processing is not as good as aluminium, and aluminium heat sink can fully meet the requirements of LED heat dissipation, so in the LED metal heat sink to aluminium heat sink is dominant, copper heat sink is not rare. Aluminium heat sinks, generally including die-cast aluminium and drawn aluminium heat sinks of two kinds. The main reason is the high thermal conductivity of aluminium metal, small specific gravity, easy processing, cheap price, etc.. In recent years, in order to achieve "lightweight" products, thermally conductive plastic as a new material is gradually entering the lighting market.

Thermally conductive plastics are an improvement on engineering plastics by adding thermally conductive fillers to engineering plastics to improve their thermal conductivity, thus making engineering plastics, which do not have thermal properties, thermally conductive and a component of a luminaire heat sink [20]. Thermally conductive plastics require the same moulding process as ordinary engineering plastics, but require the addition of thermally conductive fillers to improve the thermal performance of the plastic. Thermally conductive plastics are filled with thermally conductive fillers such as aluminium oxide, magnesium oxide and zinc oxide, as well as metal powders, graphite and carbon fibres, etc. Thermally conductive plastics are lighter, more flexible and do not require subsequent processing [21].

Theoretically speaking its thermal conductivity is not high, the thermal conductivity of the best thermally conductive plastics is only 100W(/m.K), while the thermal conductivity of aluminium is 80-160w/(m.K). Thermal conductivity can be achieved by conduction, convection and radiation. The surface area of a heat sink made of thermally conductive plastic is no smaller than that of aluminium, so it is no worse than aluminium in terms of convection heat dissipation. In fact, due to the plastic's plasticity, designers can easily increase the surface area of the heat sink, such as increasing the number of heat sinks or adding thin-walled objects. Thermally conductive plastics have a surface emissivity of up to 0.95, which effectively reduces the surface temperature of the luminaire. For fish collectors working at sea, the corrosion of the heat sink is also a consideration, especially for fish collectors working underwater, a problem that can be solved by thermally conductive plastics as opposed to aluminium heat sinks.

Although, thermally conductive plastics have many advantages, there is a need for further innovation in specific applications. For example, the thermal conductivity of thermally conductive plastics is relatively small and expensive. At the same time, as a new material, thermally conductive plastics are not well known in the market, and many manufacturers are not familiar with them, but still choose the relatively mature process of metal materials. So the road to the application of thermally conductive materials still needs more researches.

Conclusion

High-powered fish collection lamps and ordinary high-powered LED's have much the same technical problems in terms of heat dissipation. In addition to improving the structure of the lamps, there is a need to increase research into lamp materials in order to reduce energy loss and truly achieve energy efficiency.

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