Light-Emitting Diodes for Space Applications

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***Abstract* — The LED device for illumination in space application has been well done in the past few years, including the in cabin application on bio-science satellite in 2007 and out cabin application on spacecraft in 2008 to shine on the first step in space of Chinese astronaut. The optical simulation has been performed to optimize the brightness of LED lamp. The thermal property of assembled LED lamp have been experimental characterized combing with the numerical simulation to improve the precision of p-n junction temperature determination for LED packed in the lamp. The measurement precision on the LED p-n junction temperature is improved to the value better than 1K.**

I. INTRODUCTION

The illumination-tech has developed rapidly especially in the area of white-light illumination which provoke a vital improve in the illumination technology[1]. Since it has the features like low processing voltage and long-life with high reliability, the light emission diode (LED) illumination-tech would be better fit for the space illumination. In the application of the space illumination, the reliable of the LED equipment comes to be the key problem. The measurement precision on the temperature of the p-n junction in LED has been one of the main methods to research the reliability of the LED lamp.

II. RESULTS

Because of the LED chip we should measure is encapsulation in the lamp, the pin temperature measuring method which considered as a high accuracy way cannot be applied to it. The spectroscopy method appears to be the best approach. But the accuracy of blue/white spectrum method cannot reach the level at 1 K which can be utilized in the reliability research[2]. Tiis paper we will use the electro-luminescence peak shift.

A. The junction temperature measurement based on the electro-luminescence peak shift

First of all we should directly measure the change encounter to the blue light in LED's irradiance spectrum peak-position, λ_p, by the change of temperature. We set the impulse voltage as 3V with width 10ms, cycle duty 1%. Then we acquire the measured results as shown in figure 1. The irradiance spectrum of the LED has been showed as the insert in the figure 1. The circle points are the spectrum peak-position shift $\Delta\lambda_p$ gained with fitting method under different junction temperature. These are the data shifting from the LED blue light irradiance peak-position at 300K. The solid line stands for the relationship between $\Delta\lambda_p$ and $(T\text{-}300)$ through the conic function fitting method. The expression is as below:

$$\Delta\lambda_p = a(T-300) + b(T-300)^2$$

$$a = 3.50\times10^{-2} \pm 4\times10^{-4}, b = (87\pm5)\times10^{-6}$$

The irradiance peak-position shift amount caused by each1K junction temperature change of the LED chips under different temperature can be expressed as follows:

$$\frac{d(\Delta\lambda_p)}{dT} = a + 2b(T-300)$$
$$= 3.50\times10^{-2} + 1.7\times10^{-4}(T-300)$$

Read from this relationship we found out that the temperature data fluctuation deduced from the differences between experiment-dot and fitting curves are as follow: The average mount deviation of temperature is 0.2K, the maximum deviation is 0.6K, the median deviation is 0.3K, the deviation distribution standard deviation is 0.2K. We can conclude that the junction temperature accuracy is better than 1K.

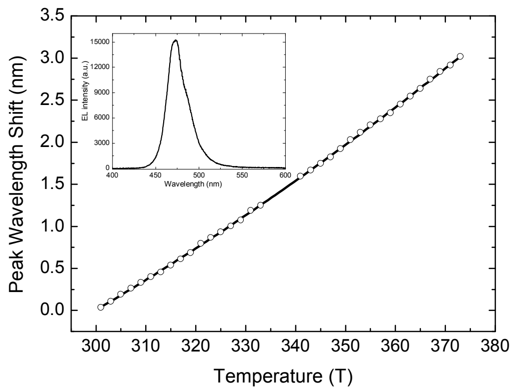

Figure1. the relationship between the blue-light irradiance peak-position and the temperature

B. The measurement of junction temperature for LED chip packaged in lamp

Infer from the data given by figure 1, we can conclude the relationship between junction temperature relative to 300K $(T\text{-}300)$ and $\Delta\lambda_p$ as following:

$$(T-300) = c\Delta\lambda_p + d\Delta\lambda_p{}^2$$

$$c = 27.8\pm0.2, d = -1.22\pm0.08$$

Figure 2 deduce the change amount of junction temperature utilizing the formula above. The spectrum band used for the fitting is around the blue light peak around 451nm as shown in the insert of figure 2. The triangle dot and circle dot represent the lamp junction temperature change under two different thermal environment. Under these two different conditions, the

LED chip junction temperatures exceed 15K and 12.5K to the room temperature, respectively. We can find out from the figure 2, the results with measure of spectrum peak-position shift give a stabilized the junction temperature within 1K for those measured in different time. It demonstrates this method can control the error of LED-chip junction temperature measurement within 1K.

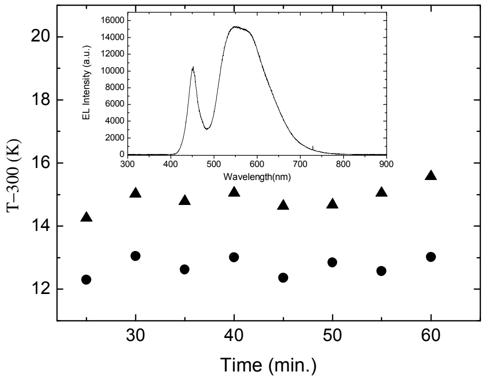

Figure 2 The measure data after lamp heat stable , the triangle dot and circle dot stand for the junction temperatures in same lamp but with two different thermal environment.

C. The optical design of lamp

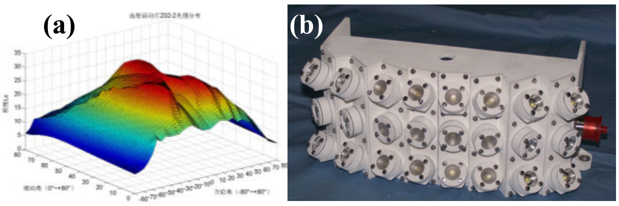

Figure 3 (a) The lamps light intensity distribution after lamps optimize, (b) The finished LED white light illumination for Shenzhou-7 spaceship.

After secondary optics design, we made a special distribution of high-power LED illumination system so that we can ensure the emission light can assemble into the range of 80^{o}. The optical intensity is shown by figure 3(a). The lamp structure for external capsule activity adopted FRESNEL LENS design. This external capsule illumination lamp provids a stable white-light illumination without light intensity sparkling for astronaut's activities out of the cabin. And also supply the external camera capturing clear photos of actions out the cabin.

D. The successful space application of LED lamp

At the night of 26 Sept. 2008, astronaut performed the on-orbit electrical test for external-cabin LED lamp. The LED lamp had a good performance with fine illumination effect.(Showed by figure 4).

At 16:10 p.m. of 27 Sept. 2008, the external-cabin activity lamp started to work, at 16:30 the astronaut began his external activity. During the whole process, the external cabin activity lamp works well with stable performance. All tech-index match the required level. After 90 minutes lasting illumination, the LED led an perfect end of the illumination task!

Figure 4 The status of LED white light illumination lamp applied to external cabin. The arrow indicates the LED white light illumination equipment. The flyer on the left side is shenzhou-7 spaceship.

In the item of Shi Jian-8 recoverable satellite, the LED illumination technology has provided high efficiency with high reliable white/red LED combination illumination for the photosynthesis under the circumstance of microgravity in satellite cabin. The green superior botanic photosynthesis needs enough light intensity. However, the electrical power provide in the satellite is very limited so that we choose high irradiance efficiency as the illumination source. With low-power consumption, the white light LED lamp provide reasonable illumination intensity in the illumination cycle research about the botanic growth. Also the LED lamp provide proper light intensity for microscope camera capturing. The photos (figure 5) transmitted from satellite show us the well growth of plants in the space lightened by LED illumination.

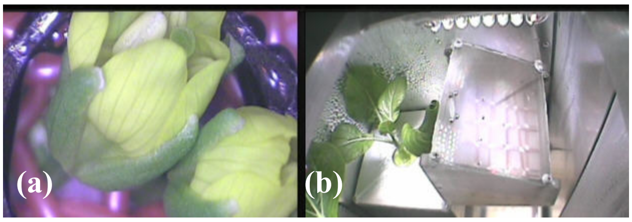

Figure 5 The photos captured on the shijian-8 satellite (a)the plant grown under the illumination of LED lamp, (b) LED illumination lamp equipped in the plant growth box

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