

## Study on photothermal coupling of COB lamp belt

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**Abstract.** With the rapid development of LED technology, the lighting effect of LED lamp belt in the atmosphere lamp has been unable to meet the needs of the modern market, and the COB lamp belt has gradually entered the public field of vision due to its advantages of high light uniformity, low junction temperature and large luminous Angle. In this paper, the stability, light uniformity, junction temperature and other performance of the two kinds of lamp belt under different color temperature and different power were analyzed by setting contrast experiment. It was found that LED lamp belt had uniform light and poor heat dissipation effect due to chip distribution characteristics, and it would accumulate a lot of heat and appear color shift phenomenon when continuously lit. The COB lamp belt can not only maximize the heat dissipation performance of the substrate, but also achieve more uniform light distribution by the way of multi-chip arrangement. The relationship between the thermal performance and chip spacing is analyzed by optimizing the design, which plays a guiding role in the actual production of the lamp belt

**Keywords:** COB lamp belt; Optical performance; uniformity; thermal performance.

### 1. Introduction

With the gradual maturity of LED technology, LED devices have been applied to more and more occasions, the light emitted by the light source can not only reasonably constitute the space, but also effectively change the space. In addition, it can beautify an interior space, but it can also seriously damage it. Light can illuminate the space, and different light can also create different emotional appeal and atmosphere, and the artistic conception of the space is also different [1]-[4].

At present, in the lighting decoration of the hotel on the market, in addition to the traditional lamp design such as ceiling lamp and porch lamp, COB lamp belt or LED lamp belt is also used to foil the lighting of the hotel's environmental atmosphere[5]. In addition, the lamp belt has been applied in intelligent mirror lighting, outdoor lighting, home decoration lighting and other aspects [6]-[7].

COB(Chips on Board) is a technology to solve the LED heat dissipation problem. The bare chip is attached to the interconnection substrate with conductive or non-conductive adhesive, and then the electrical connection is realized by lead bonding [8]-[9]. A COB strip is a strip that encapsulates the chip on a soft board. The chip mostly adopts flip chip, which is linear solid crystal on PCB board, and then drops a layer of encapsulation glue mixed with phosphor powder directly on the chip surface. Through refraction, reflection and interaction with phosphor, the light emitted by the chip in the encapsulated colloid uniformly emits light of different colors and color temperatures [10].

However, in the application of hotel decoration, outdoor lighting and home decoration, the traditional LED lamp belt has a strong sense of granularity after lighting because of the large chip spacing, which affects the overall aesthetics. In addition, in order to ensure the lighting effect, the power of a single lamp bead is large, and the strong light emitted will have a certain impact on human eyes. Therefore, in order to avoid such particle sensation affecting the lighting effect, COB lamp belt is developed, as shown in Figure 1.

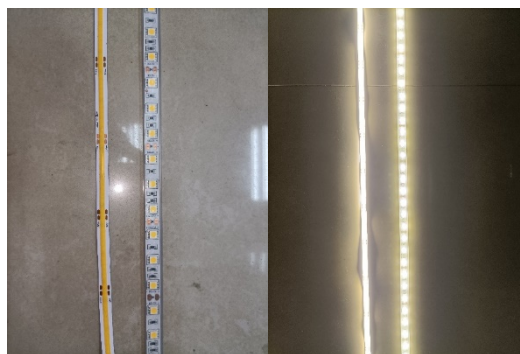


FIG. 1 Schematic diagram of LED lamp belt and COB lamp belt

Compared with LED strip, COB strip has the following advantages : (1) due to the structural characteristics of COB strip, the luminous surface is a linear colloid; And ordinary lamp bead type lamp belt, its structure is a luminous lamp bead, pasted on the PCB board. Therefore, the light emitted by the COB lamp belt is much more uniform, linear, and no light spot. (2) Because the COB chip is directly solidified on the PCB board, the heat of the chip can be quickly transferred to the PCB board. Therefore, the chip heat dissipation speed of THE COB lamp strip is faster than that of the beaded lamp, and the light decay of the COB lamp strip is smaller and the life is longer. (3) The luminous Angle of COB lamp strip can reach 180°.

At present, no scholars have conducted comprehensive research on COB lamp belt and traditional LED lamp belt, so users can only judge the performance of the lamp belt through naked eye recognition, and there is a lack of quantifiable data to analyze and compare the performance of the two kinds of lamp belt, so as to provide guidance for users .In this paper, by comparing the thermal and optical properties of LED and COB, the most suitable ambient lamp for the current lighting market is analyzed. Modeling and simulation are carried out for the structure of COB lamp belt, the influence of different factors on the performance of COB lamp belt is analyzed, and the best scheme is analyzed, which has guiding significance for the practical application of COB lamp belt.

## 2. Experimental Preparation

In order to ensure the accuracy of experimental results, control variable method is adopted in this paper. The selected variables are the type of lamp belt, color temperature and power, and the optical performance and thermal performance of the lamp belt are tested. In order to ensure the heat dissipation effect and avoid the influence of different substrates on the lamp belt causing inaccurate experimental results. The LED strip and COB strip selected in this experiment are both flexible substrates, and their PCB boards have the same structure, as shown in Figure 2.

The lamp belt selected in this paper is shown in Figure 1. COB lamp belt with same voltage, same color temperature and different power and COB lamp belt with same voltage, different color temperature and same power are selected for comparison, and the influence of the number of chips on the light uniformity and heat distribution of COB lamp belt is analyzed. The influence of different phosphors on COB lamp band uniformity and heat distribution was analyzed.

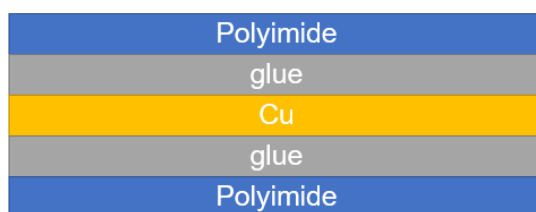


FIG. 2 Schematic diagram of PCB circuit board

The specifications of the lamp belt selected for this experiment are shown in the following Table 1.

Tab 1 COB lamp belt specifications

| Voltage/ (V) | Color temperature/ (K) | Type | Power/ (W) |
|--------------|------------------------|------|------------|
| 24V          | 3000K                  | COB  | 12         |
| 24V          | 3000K                  | COB  | 15         |
| 24V          | 3000K                  | COB  | 18         |
| 12V          | 3000K                  | COB  | 12         |
| 12V          | 4000K                  | COB  | 12         |
| 12V          | 6000K                  | COB  | 12         |
| 12V          | 3000K                  | LED  | 12         |
| 12V          | 4000K                  | LED  | 12         |
| 12V          | 6000K                  | LED  | 12         |

In order to obtain optical data and thermal data, optical measurement experiment and thermal measurement experiment were carried out respectively. The model of sIS-3\_2 0m steel photometric integrating sphere \_R98\_ side open  $\phi$ 700mm and haas-2000 high precision rapid spectral radiometer were used to measure the optical properties of COB flexible lamp belt. Led-t300b instrument was used to measure the junction temperature of the flexible lamp belt, as shown in Figure 3.

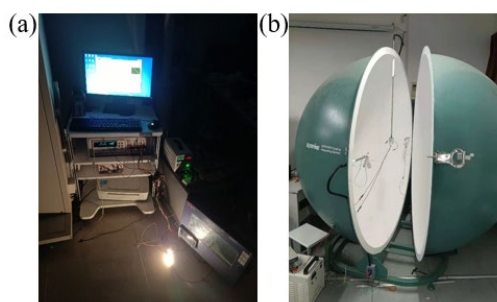


FIG. 3 Experimental instrument (a) junction temperature tester; (b) integrating sphere

### 3. Test and analysis of optical properties of lamp belt

Put the above nine specifications of the lamp belt into the integrating sphere for transient measurement, use a constant current source to light the lamp belt, and constantly increase the output of the current, observe the change of peak wavelength.

#### 3.1 Stability test

As shown in Figure 4, the COB strip has a more stable lighting advantage compared to the LED strip. Figure 4(3) shows the wavelength change rate of the LED strip after the current is increased. It can be seen that the LED strip at 3000K is relatively stable, and the wavelength does not change with the current after the current is changed. However, the LED strip at 4000K and 6000K both show certain degree of blue shift and red shift. Among them, red shift phenomenon is the most serious. First we explain why there is such a large red shift. As the current increases, the temperature of the chip increases and the band gap of the blue LED light source decreases. Therefore, the peak wavelength shifts to a longer wavelength. This phenomenon can be explained by a common relation between the band gap and temperature in semiconductors, as shown in Formula 1.

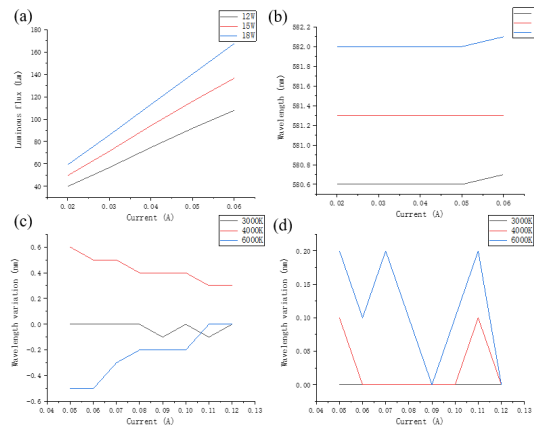


FIG 4 (a) COB light flux changing with current at different powers ;(b) COB light peak wavelength changing with current at different powers; (c) LED light peak wavelength changing with current at different color temperatures ;(d) COB light peak wavelength changing with current at different color temperatures

$$E_g = E_0 - \alpha T^2 / (T + \beta) \quad (1)$$

Where,  $E_0$  is the band gap at color temperature 0K,  $\alpha$  and  $\beta$  are fitting parameters. Therefore, according to the formula, red shift will occur when the LED lamp with color temperature of 4000K increases the current.

However, the LED light band with a color temperature of 6000K appears blue shift. According to Formula 1, the light band will appear red shift, but the fluorescent powder conversion efficiency of 6000K lamp bead is lower than that of 4000K fluorescent powder, so with the increase of current, More blue light from the light source, low phosphor conversion efficiency can not completely turn redundant blu-ray, so on the basis of redshift, peak wavelength and the blue shift of the situation, so that's why the current is added under the condition of the same variable, 4000 k light with a red shift and 6000 k light with a blue shift is different, The phenomenon of blue shift is smaller than that of red shift [12].

Whereas COB lamp tape, there was no obvious peak wavelength of the blue shift or red shift phenomenon, this is because the COB lamp with smaller power itself, the heat generated by the small, as shown in Figure 4, relative to the LED lamp belt, COB lamp belt junction temperature is lower, so the same electrical flow, low COB lamp with increase of temperature, temperature change is not obvious, Therefore, the peak wavelength shift of the COB lamp band is not obvious, but only slightly shifted to the long wavelength direction [13].

Then we analyze the steady-state performance of the COB lamp belt, increase the current continuously, and measure the luminous flux and peak wavelength of the COB lamp belt ten minutes after each increase of the current. As shown in Figure 4(1), under the same color temperature, COB strips with different chip densities lead to different power of the strip. The power of the strip gradually increases, and its luminous flux also increases steadily, presenting a good linear relationship. This is because as COB lamp with a large number of uniform distribution and the low power chip, so the substrate can act as good heat dissipation effect, within the scope of a certain power, with the increase of power, the PN junction temperature does not have a larger variation, which will not lead to chip for p-n junction temperature too high luminous efficiency reduce state is nonlinear.

Also, with the increase of current, the lamp with peak wavelength redshift phenomenon, principle as mentioned above, the power increases because of the solid crystal chip number increases, when the increase in the number of chips, increase total quantity of heat, but the base plate of the heat dissipation efficiency is constant, with the power increase, will lead to more heat accumulation within the p-n junction, prompted the LED chip of PN junction temperature rise, That leads to a redshift situation.

### 3.2 Uniformity test

In order to measure the illumination uniformity of the two lamp belts, we fixed the above LED lamp belt and COB lamp belt on the shelf, selected 33 points on the plane below the shelf, and measured the illumination intensity of the lamp belt. The experimental scene and results are shown in the figure below.

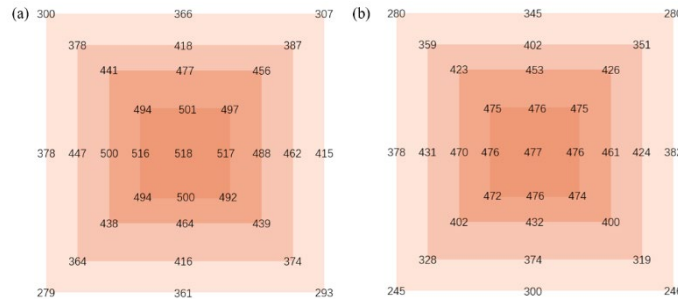


FIG. 5 (a) COB lamp light distribution diagram; (b) LED lamp light distribution diagram

Aiming at the calculation method of uniformity, we use nine-point illuminance measurement method to study the lighting uniformity of the lamp belt. The measurement plane was divided into nine regions, and the spectral irradiance of the central point of each region was measured with a spectral irradiance meter. This technical standard gives the distribution of test points on the rectangular measuring plane, as shown in FIG.6 [14].

After the test of each measuring point is completed, the following formula is used to calculate the radiation uniformity  $U_e$ .

$$U_e = \frac{E_{min}}{E_{avg}} \times 100\% \quad (2)$$

$$E_{avg} = \frac{\sum_{i=1}^9 E_i}{9} \quad (3)$$

Where,  $E_{min}$  is the minimum value of spectral irradiance measured at the central points of nine regions;  $E_{avg}$  was the arithmetic mean value of spectral irradiance measured at the central points of the nine regions.

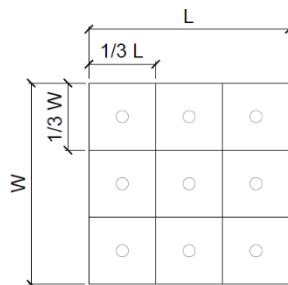


FIG. 6 Schematic diagram of irradiance uniformity measurement point

According to Formula 2 and 3, 9 points are selected from the light distribution diagram, and the light uniformity of COB lamp belt and LED lamp belt is shown in the following formula respectively.

$$\frac{E_{min}}{E_{avg}} = \frac{438}{\frac{441 + 500 + 438 + 464 + 439 + 488 + 456 + 477 + 518}{9}} = 93.39\% \quad (4)$$

$$\frac{E_{min}}{E_{avg}} = \frac{403}{\frac{423 + 470 + 407 + 432 + 403 + 461 + 426 + 453 + 477}{9}} = 91.28\% \quad (5)$$

At the same time, according to the physical object of the lamp belt, the model was established and simulated in Tracepro. In order to ensure better comparison effect of illumination uniformity, the luminous flux of the light source was set to 15Lm. The simulation results are shown in the figure below.

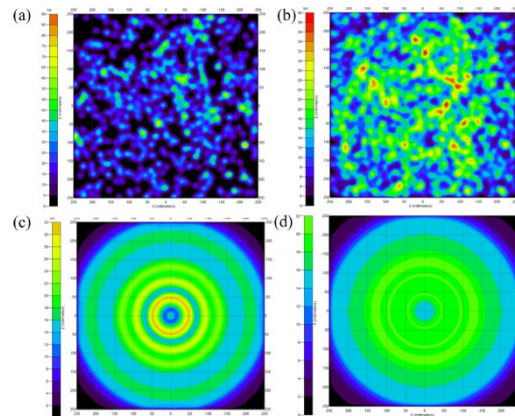


FIG. 7 (a)LED lighting simulation diagram (b) COB lighting simulation diagram (c)LED lighting simulation diagram rotation symmetry (D) COB lighting simulation diagram rotation symmetry

As can be seen from the figure above, when the light flux is set at the same time, although the light intensity illuminating the plane LED light strip has a higher intensity, this is because the light emitted by LED light source is Lambert-type light source. When the light source is distributed at more points, it cannot concentrate the light better, so the maximum light intensity of COB light strip is lower than that of LED light strip. However, the uniformity of LED lamp belt is poor, because the chip spacing of LED lamp belt is far away, and the divergence Angle of Lambert-type light source is large, so the light cannot fully cover the irradiation area. And COB lamp with chip configuration is relatively dense, adopt the way of a glue whole encapsulation, so look no obvious sense of particles on the vision not only, and light evenness are also high, but the LED lamp with chip spacing is bigger, although individual chip lighting intensity is higher, but easy to form particles on the vision feeling, lighting effect is less in COB lamp tape, And the light uniformity is not high.

#### 4. Thermal testing and analysis

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##### 4.1 Thermal analysis

Led-t300b instrument was used to measure the junction temperature of the flexible lamp belt. The COB lamp belt with the same power and different color temperature and the COB lamp belt with different power and the same color temperature were placed in the thermostat, and then calibrated and measured. As the current increases from 10mA to 120mA, the junction temperature of LED chip changes as shown in the Figure 8.

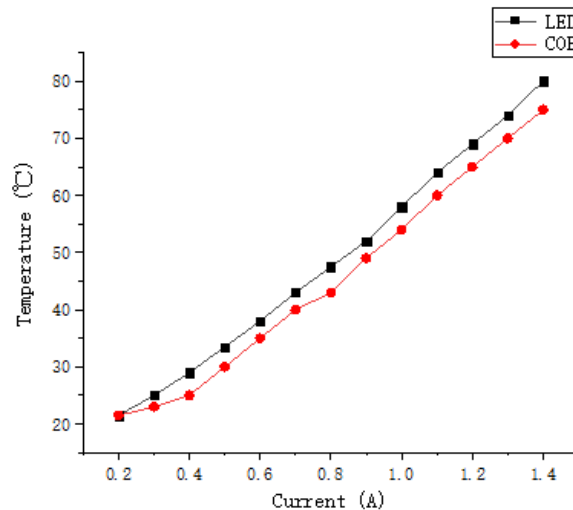


FIG. 8 Diagram of junction temperature with current

As shown in the Figure 9, the junction temperature of LED strip with the same color temperature and the same power is higher than that of COB strip. Because 5050 chip package is adopted for LED strip, the distance between chips is large, and the heat of the chip itself is high, so the heat cannot be better released. The heat distribution is shown in the simulation figure. COB lamp belt by packaging small chips on a strip substrate, although the chips are more dense, but the temperature of a single chip is not high, chip spacing is more favorable for the heat dissipation of the lamp belt.

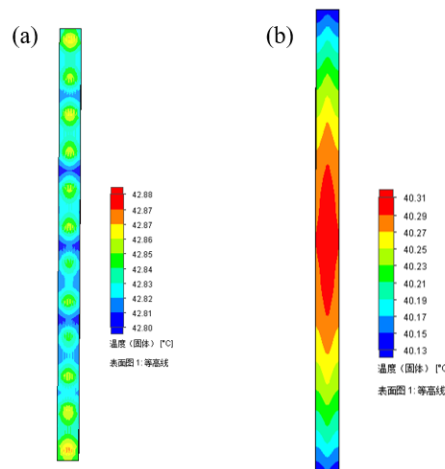


FIG. 9 (a)LED lamp thermal simulation diagram ;(b) COB lamp thermal simulation diagram

#### 4.2 The optimization design

By the picture above, LED substrate, uneven distribution of temperature and heat are mainly concentrated in the position of the chip, lead to the edge of the base board does not have the effect of heat dissipation, properly so that the cooling effect is relatively poor, lead to chip junction temperature is higher, and COB lamp with chip for distribution of intensive, and interval is the same, so better to transfer the temperature of the chip to the edge of the substrate. According to the characteristics of the COB lamp with heat distribution optimization design of COB lamp, lamp with the power of the whole set is 1.2 W, change the chip distribution way, in order to better use of the base plate heat dissipation effect, will use dislocation distribution chip and heat distribution as shown below, with the increase of chip transverse spacing, substrate can play a better role of heat dissipation, Heat is no longer concentrated in the center of the substrate, but diffuses like the edge, so as the cross chip spacing increases, the maximum temperature of the strip decreases.

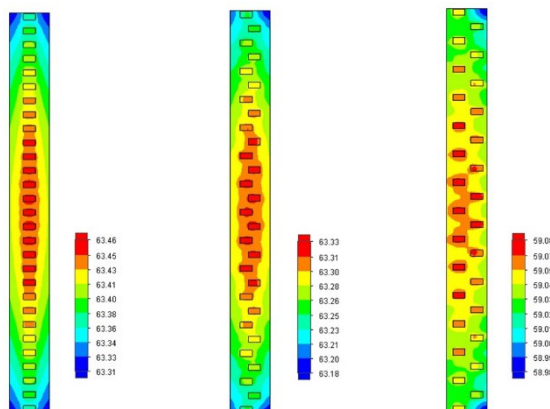


FIG. 10 Heat distribution diagram of lamp strip with different chip arrangement

## 5. Conclusion

As far as the lamp belt is concerned, it is used as an atmosphere lamp in most cases, so its illumination stability and illumination uniformity are the most important performance parameters, which determine the merits of the lamp belt. This paper analyzes the reason why LED strip is inferior to COB strip in optical and thermal performance by comparing LED strip with COB strip. The stability of the COB strip was also tested, indicating that it is suitable for the current atmosphere lamp market. According to the way of thermal simulation, the COB lamp strip is simulated, and its chip layout is changed to optimize its thermal optimization, so as to find a better heat dissipation scheme and ensure the reliability of the device.

It is important to note that we are not just comparing the two bands to analyze their performance differences. By analyzing the characteristics of the chip and the influence of its layout on the optical and thermal properties, the influence of the chip layout on the overall device can also be applied to other devices, which can play a certain degree of guidance to the actual production.

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