Systematic Research on the Heat Dissipation Channel of High Power LED Street Lamps

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Abstract. This article mainly studies the thermal characteristics of light source of the street lamp, and systematically analyzes the effective ways of heat transfer and heat dissipation of street lamp. Based on experiments and finite element simulations, the heat dissipation channels of street lights were studied, and the weak links of heat transfer and heat dissipation were analyzed, and the heat dissipation structure of street lamp was optimized. The experimental results show that the junction temperature of the chip is lower than 90 °C in the steady state, and the luminous efficiency decreases by 5.93%. In order to ensure the efficiency and reliability of the street lamp, it is recommended that the junction temperature of the street lamp be controlled below 85 °C. After analyzing the arrangement of the chips, silicone grease with different thermal conductivity and aluminum substrate, it is found that the substrate is the bottleneck affecting effective heat transfer, and the use of diamond-like carbon metal core printed circuit board (DLC-MCPCB) can reduce the junction temperature by 17.04 °C. Through the grid design of shell of the street lamp, the heat dissipation effect of the street lamp surface can be enhanced, and the junction temperature can be reduced by 7.04 °C. Based on these studies, the optimal design model of street lamp was obtained, which provides guidance for practical applications.

1. Introduction

LED has the characteristics of low light decay, high luminous efficiency [1-3], fast response and green environmental protection [4]. It has become an indispensable part of lighting and is widely used in various fields such as commercial lighting, road lighting, automotive headlights and display screens [5, 6].

However, the heat dissipation of the LED is the main problem affecting its stable application. The low internal and external quantum efficiency of the LED chip will affect its heat dissipation [7-9]. There are also experiments to prove that the luminous flux and luminous efficiency of street lamps have a
linear decreasing relationship with junction temperature [10-12]. Therefore, reducing the junction temperature of the street lamp can ensure that the luminous flux changes within a reliable range.

The working temperature of the LED street lamp can be lower than the reliability temperature by passive heat dissipation and active heat dissipation [13, 14]. In addition, many researchers have studied the structure, material and heat dissipation module of street lamps. They have invented different structures such as flexible substrates combined with aluminum alloy heat sinks, U-shaped aluminum flat heat pipes (AFHP) and hollow trapezoidal baffle radiators [15-19], which not only improve the heat dissipation capacity, but also reduce the weight and flow resistance of street lamps.

At present, the most widely used substrate is metal core printed circuit board (MCPCB) [20]. In addition, ceramic substrates and high thermal conductivity substrates with CIC (Cu-invar-Cu) as the core of the PCB are gradually being used in high-power LED street lamps, but the high price limits their wide use in street lamps [21, 22].

The commonly used thermal interface materials (TIM) is silicone grease, which has strong adaptability, but the large-area coating operation is not convenient for long-term use at high temperature. Therefore, the use of new TIMs such as carbon nanotubes and silicone oil mixed TIM and integrated graphene sheets can ensure the surface wettability of the material and improve the heat transfer ability of the street lamp [23, 24], and reduce the contact thermal resistance of the joint surface between the heating and heat dissipation units.

The heat dissipation module directly affects the reliability and service life of street lamps. In order to enhance the heat radiation effect of the radiator, researchers invented nano-metal coating and magnesium coating to significantly improve the heat dissipation effect of LED street lamps [25, 26]. In addition, the spacing, length, height and number of fins have a significant impact on the convective heat transfer effect of street lamps [27-29]. Kang et al. [30] proposed a multi-layer heat dissipation module with a substrate connected to a heat pipe and fins, which significantly improved the heat dissipation performance of LED street lamps.

Although these studies greatly improve the heat dissipation performance of LED street lamps, the increasing power of street lamps leads to higher heat dissipation requirements. With the increase of street lamp thermal power density, the heat dissipation of street lamp is mainly considered from two aspects. One is to improve the heat dissipation channel of street lamp and transfer heat from chip to radiator. The second is to change the structure or material of the radiator to transfer the heat from the radiator to the outside world, so as to strengthen the convection heat dissipation.

Therefore, in order to control the temperature effectively, the path that affects the heat transfer and heat dissipation of street lamp is analyzed comprehensively. The influence of chip arrangement, different thermal conductivity of silicone grease, substrate and radiator on heat transfer and heat dissipation is analyzed. It is found by experiment and simulation that the substrate is the key to affect the heat transfer, and the different structure of the fin affects the heat dissipation effect to a certain extent. On this basis, the street lamp is optimized and the optimal structure model is obtained to ensure that the temperature rise of the chip is controlled at about 40 °C.

2. Experiment and simulation

2.1. Experiment

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2.1.1. Research object. A 130W street lamp was selected as the research object. The complete structure includes power supply, chips, substrate, copper plate, radiator, lenses, thermal interface material, fastener and other components (Fig. 1). Because fasteners have little influence on heat dissipation, they are neglected.
2.1.2. **Experimental platform and equipment.** A thermal test platform was established to study the heat dissipation process of street lamps. It consists of street lamp, T-type thermocouple, paperless recorder, data processing system and support rod (Fig. 2). In the experiment, the paperless recorder records data every 10 seconds.

![Figure. 1 Structure diagram of LED street lamp.](image)

2.1.3. **Experimental process.** Thermocouples are connected to the chip, substrate, copper plate and shell respectively to measure the temperature of the heat dissipation channel (Fig. 3).

![Figure. 2 Thermal test platform.](image)

The measurement accuracy of thermocouple is ±1 °C. In order to ensure the accuracy of the test, calibration must be performed before the start of the experiment. The calibration adopts the comparison method. There are errors in thermocouple measurement, which mainly come from measurement error of ±1 °C, data acquisition error of 0.3% and influence error of instant dry glue of ±1 °C. Because the
error results are relatively small to the experimental results, the data acquisition system can read directly, that is T=t [31].

In addition, a substrate was used to study the effect of junction temperature on the luminescence of the street lamp. After connecting a thermocouple to the negative electrode of the chip, the integrating sphere was used to test the luminous flux and luminous efficiency changes of street lamps at different junction temperatures.

2.1.4. Thermal resistance of the street lamp. The thermal resistance of the street lamp includes LED thermal resistance and LED external thermal resistance. The thermal resistance of a single chip can be defined as:

\[ R = \frac{\Delta T}{P} \]  

Where \( R \) is the thermal resistance of the chip, \( \Delta T \) is the average temperature difference between the two ends of the chip, and \( P \) is the thermal power of the chip.

The external thermal resistance of LED is:

\[ R_{\text{ext}} = R_{\text{cond}} + \frac{1}{R_{\text{conv}} + \frac{1}{R_{\text{rad}}}} \]  

Where \( R_{\text{cond}}, R_{\text{conv}}, \) and \( R_{\text{rad}} \) are the conductive heat resistance, convection thermal resistance and radiation thermal resistance.

In the entire heat dissipation system, the longer the heat dissipation channel of the street lamp, the greater the thermal conduction resistance.

(1) Heat conduction

The total heat resistance of the heat conduction part is equal to the sum of the heat conduction resistance of each link. It can be calculated by Fourier’s law.

\[ R_{\text{cond}} = \frac{\delta}{A \cdot \lambda} \]  

(2) Convective heat transfer

The heat transfer between shell and environment is mainly through convective heat transfer, which belongs to the form of natural convective heat exchange in large space. Therefore, the coefficient of convective heat transfer can be solved by the Nusselt number [32].

\[ N_u = c(Gr \cdot Pr)^n \]  

\( Pr \) is the Prandtl number, it can be solved by qualitative temperature. The Grashof number is defined as [33]:

\[ Gr = \frac{g \beta \Delta T L^3}{\nu^2} \]  

Where \( \beta=1/T \) is the coefficient of volume expansion, \( L \) is characteristic length. The range of the Grashof number is from \( 3 \times 10^5 \) to \( 3 \times 10^{10} \).

The heat transfer coefficient of the street lamp can be obtained.

\[ h = \frac{N_u \lambda}{L} \]  

(3) Radiant heat transfer

The radiant heat transfer between shell and environment can be calculated by the Stefan-Boltzmann law.

\[ Q_{\text{rad}} = eA\sigma(T_{\text{sh}}^4 - T_{\text{a}}^4) \]  

Where \( e \) is the emissivity of the shell and \( \sigma=5.67 \times 10^{-8} \text{ W/(m}^2\cdot\text{K}^4) \) is the Stefan-Boltzmann constant.
2.2. Finite element simulation

2.2.1. Theoretical basis. The thermal simulation of street lamp is carried out by using finite element software FloEFD. The flow state of the fluid is known by the differential equations of convective heat transfer [34].

Because natural convection is mainly in the direction of gravity of street lamps, it can be reached to \( Dn \) according to the continuity equation and the momentum differential equation.

\[
Dn = -\frac{1}{\rho} \cdot \text{grad}(p) + \frac{\mu}{\rho} \cdot \nabla^2 n
\]  

(8)

Where \( n \) is the coordinate in the normal direction

When only gravity is considered, the following formula can be obtained.

\[
Dn = g - \frac{1}{\rho} \cdot \text{grad}(p) + \frac{\mu}{\rho} \cdot \nabla^2 n
\]  

(9)

2.2.2. Setting of initial conditions. According to the structure of street lamp, its initial parameters are obtained (Table.1).

### Table. 1 Initial parameters of the model.

| Project        | Area/(m²)   | Thickness/(m) | Thermal conductivity /(Wm⁻²K⁻¹) |
|----------------|-------------|---------------|---------------------------------|
| Chip           | 9×10⁻⁶      | 5×10⁻⁴        | -                               |
| Substrate      | 1.15×10⁻²   | 2×10⁻³        | 1.5                             |
| TIM            | 3.519×10⁻²  | 3×10⁻⁴        | 5                               |
| Copper plate   | 6.88×10⁻²   | 5×10⁻³        | 398                             |
| radiator       | 1.995×10⁻¹  | 4×10⁻³        | 96.2                            |

In the simulation, 80% of the street lamp power is taken as the thermal power, so the thermal power is 104 W.

According to the defined initial parameters and the actual shape of street lamp, a strict three-dimensional model of street lamp is built by Creo software (Fig. 4).

![Street lamp model](image)

**Figure. 4** Street lamp model.

The simulated ambient temperature is consistent with the experimental temperature, and controlled at (18±0.5) °C without obvious air flow. The parameters of simulation are shown in Table 2.
Table 2 Simulation parameters.

| Project                  | Parameter                        | Project                  | Parameter          |
|--------------------------|----------------------------------|--------------------------|--------------------|
| Computational domain     | 720×380×230 mm³                  | LED heating power        | 102.4 W            |
| Ambient temperature      | 18 °C                            | Radiation rate of radiator | 0.27               |
| Gravity acceleration     | 9.8 ms⁻²                        | Heat transfer coefficient | 5 W/(m²·K)         |
| Atmospheric pressure     | 0.101 Mpa                        | Computational mesh       | 3.41×10⁶           |

According to the data in Table 2, the model is set up and meshed. In order to save the time and memory of simulation calculation, the calculation domain should be reasonable. The number of nodes in the mesh is 3.41×10⁶ (Fig. 5). After setting the parameters and initial conditions, set the tracking target, and finally start to solve the results.

**Figure 5** Calculation domain diagram (left) and calculation mesh (right) of LED street lamp.

3. Result analysis and optimization design

3.1. Comparison of experimental and simulation results

The experimental results are basically consistent with the simulation results, which shows that the experimental design is reasonable (Fig. 6).

**Figure 6** Comparison of simulated and experimental values.
The maximum temperature of both is less than 90 °C, and the temperature of the substrate is close to that of the chip. The maximum temperature difference is between the substrate and the silicone grease. Therefore, it is preliminarily considered that substrate and silicone grease are the weak points of street lamp heat dissipation.

Figure 7 shows the actual test temperature and simulated temperature of the substrate. It can be seen that because the area of the substrate is much larger than that of the chip, the larger diffusion resistance leads to the highest temperature in the middle of the substrate. In addition, since the fastener can transfer part of the heat in the actual test, the actual temperature is lower than the simulated temperature. But the maximum error between the two is only 3.2%, which shows that the simulation results are reliable.

3.1.1. Preliminary results of finite element simulation. Figure 8 is the isosurface map of street lamp temperature. It can be seen that the heat is mainly concentrated at the chip and substrate. The highest temperature of the substrate is where the chip is connected, and the other parts are about 63 °C. The temperature distribution of the shell is uneven, and the maximum temperature is 58.74 °C. Because of the solid design of the shell, the heat in the shell can only be transferred to the outside through heat conduction, so the shell can be designed as a hole structure to conduct heat conduction and heat convection at the same time.

Figure 9 is the flow analysis of street lamp. After the calculation is completed, the steady state temperature of the street lamp is 83.93 °C. Due to the heat generated by the LED chip, the density of the surrounding air becomes smaller and flows upward. The flow trace diagram can be used to see the flow of the surrounding air. It can be seen from the figure that the heat mainly flows to the air through the radiator, and a small part directly flows to the air from the chip.
3.1.2. The temperature of the heat transfer channel. Figure 10 shows the temperature of heat dissipation channel of street lamp. The temperature rises the fastest in the first 600 s, and the chip and substrate rise almost simultaneously. After 600 s, the temperature rise rate begins to slow down and reaches a steady state after about 4800 s. At this time, the temperature of the negative electrode of the chip was 67.1 °C, and the temperature difference between the substrate and the silicone grease was the largest. In addition, because the heat is conducted to the outside, the temperature of the shell is still rising after the steady state.

The size of chip is 3.0mm × 3.0mm × 0.5mm, the power is 2 W, and the thermal resistance is 14 K/W [35]. In order to protect the internal structure of the chip, the thermocouple is selected to measure the negative electrode temperature of the chip, which is 67.1 °C. The relationship between junction temperature and thermal resistance is defined as [36]:

\[ T_J = T_S + R_{JS} \times P \]  
(10)

Where \( T_S \) is the temperature of the measuring point, \( R_{JS} \) is the thermal resistance of the chip, and \( P \) is the thermal power on the chip, which is 80% of chip power.

The temperature inside the chip is estimated:

\[ T_J = 67.1 + 14 \times (2 \times 80\%) = 89.5°C \]  
(11)

So the thermal resistance of the LED is:

\[ R_{thd} = \frac{89.5 - 65.4}{1.6} = 15.06K/W \]  
(12)

The results show that the actual thermal resistance of the chip is higher than the theoretical thermal resistance.
In contrast, the experimental and simulated temperature trends are the same. However, because the fasteners of street lamps can be regarded as heat-conducting elements in the actual measurement, the experimental temperature is lower than the simulated temperature. In general, the thermal simulation system built in this paper is reliable.

3.2. The effect of junction temperature on light performance

Fig. 11 is the change of luminous flux and luminous efficiency during the temperature rise of the street lamp.

![Figure 11](image.png)

**Figure. 11** The change of luminous flux and luminous efficiency with junction temperature.

When the street lamp is just turned on, the value of luminous flux and luminous efficiency is the largest, and the luminous flux is 3743.9 lm. As the junction temperature increases, they begin to gradually decrease. There is almost no change in luminous flux and luminous efficiency between 60–70 °C. After 90 °C, the two dropped sharply. When the temperature reached 120 °C, the luminous flux and luminous efficiency dropped to 71.4% and 84.69% of the original.

The luminous flux of high-power LED street lamps can be used as the criterion for the life of street lamps. The general rule is that when the luminous flux is less than 30% of the initial luminous flux, the street lamp needs to be replaced. However, due to the experimental error, the street lamp does not meet the requirements when the luminous flux in this article is lower than 20% of the initial luminous flux. According to the experimental results, when the luminous flux is lower than 2995 lm, the street lamp needs to be replaced.

According to formula 3–4, the rate of change of luminous flux during temperature rise can be calculated, and the results are shown in Figure 12:

$$\eta = \frac{\Phi_1 - \Phi_2}{\Delta T} \times 100\%$$  \hspace{1cm} (13)

Where \(\Phi_1\) and \(\Phi_2\) are the luminous flux at different junction temperatures, and \(\Delta T\) is the temperature difference at different junction temperatures.
Figure. 12 The change curve of luminous flux and its rate of change with time.

Figure 12 shows that when the junction temperature is higher than 110 °C, the luminous flux is lower than 2995 lm, which cannot meet the demand of road lighting. When the junction temperature is less than 90 °C, the rate of change of luminous flux is very small, and there is a downward trend between 60–80 °C. When the junction temperature is greater than 90 °C, the rate of change of luminous flux rises sharply, and the rate of luminous flux decreases rapidly. Therefore, the long-term working temperature of the street lamp is greater than 90 °C, which will shorten the service life of the street lamp.

3.3. Analysis of heat transfer channel
This article takes 80% of the initial luminous flux as the standard to study the heat dissipation channels of street lamps. On the premise that the luminous flux change is less than 20%, the service life and heat dissipation effect of street lamps are improved.

3.3.1. Influence of power. Figure 10 shows that there is a large thermal resistance between the substrate and the silicone grease, so only the power of the street lamp is changed to simulate to verify whether the result is universal (Fig. 13).

Figure. 13 The heat dissipation channel temperature of street lamp under different power.
The increase of the power of the street lamp will increase the input current, which causes the chip to generate more heat. It can be seen that when the power from 70 W and increases by 30 W each time until 200 W, the maximum temperature of street lamp is less than 120 °C, and gradually increases with the increase of power, it is about 15 °C per 30 W. Furthermore, the temperature difference between the substrate and the silicone grease is the largest. The reason is that the small size of the chip makes the substrate have a large diffusion thermal resistance, which leads to a large temperature difference between the substrate and the silicone grease.

### 3.3.2. Influence of chips arrangement.

In order to improve the heat dissipation performance of the substrate, the effect of different chip distribution on the junction temperature was studied. In this study, the power of the street lamp is 130W, each chip is 2 W, and it is arranged on 4 substrates in a way of 2 × 8.

The power of each chip is changed to change the arrangement of chips under the condition that the total power is 130W. Set the chip to 0.5, 1, 2, 3 and 5W respectively, and calculate the junction temperature of the chip (Fig. 14).

![Figure 14](image-url)

**Figure 14** Junction temperature of single chip at 0.5, 1, 2, 3 and 5W.

It can find that the higher the power of a single chip, the higher the junction temperature of the chip (Fig. 14). Especially when the power of single chip is 3W and 5W, the temperature of the chip exceeds the limit temperature of 120 °C, and the luminous flux is much less than 80% of the initial luminous flux. The reason is that the chip arrangement is too sparse and the diffusion thermal resistance of the substrate is too large, which causes the heat to be unable to be transmitted in time.

When the power of a single chip is 0.5, 1 and 2W, the temperature difference of the chip junction temperature is 6.69, 16.85 and 4.87 °C respectively. It can be seen that when the power of a single chip is 2W, the temperature uniformity is the best, and the heat will not accumulate.
From the perspective of the entire heat dissipation system of the street lamp, the largest temperature difference appears between the substrate and the silicone grease (Fig. 15). And the higher the power of a single chip, the greater the diffusion thermal resistance of the substrate and the greater the temperature difference. In addition, the change of chip power has almost no effect on the temperature of silicone grease, copper plate and shell.

3.3.3. Influence of silicone grease. Silicone grease directly contacts with the substrate, which may also affect the heat transfer of the substrate. Therefore, silicone grease with thermal conductivity of 0.5, 1, 3, 5 and 10W/(m·K) are selected for simulation (Fig. 16).

After changing the thermal conductivity, the temperature of the silicone grease hardly changes. The temperature distribution shows a layered distribution with the highest temperature in the center.
Figure 17 shows that the increase of thermal conductivity of silicone grease can reduce the junction temperature of the chip by about 3 °C, but the effect on the heat dissipation of the substrate is not significant, and there is still a temperature difference of about 20 °C. In addition, when the silicone grease used is different, the junction temperature of the street lamp is all less than 90 °C, and the luminous flux is greater than 3429.7 lm. Therefore, on the premise of cost saving, it can be considered that the silicone grease is not particularly expensive.

3.3.4. Influence of substrate structure and material. In general, changing the power of the chip and the thermal conductivity of the silicone grease cannot significantly reduce the temperature difference between the substrate and the silicone grease. So the influence of the substrate on heat dissipation can be considered.

Aluminum-based MCPCB (Al-MCPCB) is commonly used for LED heat dissipation. Due to poor thermal conductivity of dielectric layer, the thermal conductivity of PCB is various, and its normal thermal resistance is quite different from that of plane (Fig. 18) [37].

If the thickness of PCB is $\delta$, it is composed of copper layer with n-layer thickness of $\delta_1$ and epoxy resin with n-layer thickness of $\delta_2$, their thermal conductivity is $\lambda_1$ and $\lambda_2$, respectively, and the heat conduction in the direction with cross-section area of a is one-dimensional, then the normal thermal resistance of PCB is equivalent to each thermal resistance in series. Therefore, the normal thermal conductivity $\lambda_n$ of PCB can be obtained.

$$\lambda_n = \frac{\delta}{\frac{n\delta_1}{\lambda_1} + \frac{n\delta_2}{\lambda_2}}$$  \hspace{1cm} (14)

If the length and width of the PCB are $L$ and $W$, the plane thermal resistance is equal to the parallel connection of the parts. So we can get the planar thermal resistance $\lambda_p$ of the PCB.
\[
\lambda_\nu = \frac{n(\lambda_1\delta_1 + \lambda_2\delta_2)}{\delta}
\]

The actual length, width and thickness of MCPCB are 230 mm, 50 mm and 2 mm respectively, the plane thermal conductivity of the whole substrate is set to 160 W/(m·K), and the normal thermal conductivity is set to 1, 1.3, 1.6, 1.9 and 2.2 W/(m·K) respectively.

![Figure 19](image)

**Figure. 19** The heat dissipation channel temperature of different thermal conductivity of MCPCB.

In the figure 19, after the thermal conductivity increases by 1.2 W/(m·K), the chip temperature drops by about 10 °C. The maximum temperature difference is still between the substrate and the thermal silicone grease, but compared with the previous, the maximum temperature difference drops from more than 20 °C to 9 °C. Therefore, changing the normal thermal conductivity of the substrate can obviously improve the heat dissipation effect of the street lamp.

In order to further reduce the temperature difference between the substrate and the silicone grease, this study selected two MCPCBs and three ceramic substrates for simulation calculation (Table. 3).

| Type          | Al-MCPCB | DLC-MCPCB | Al₂O₃ | AlN  | SiC  |
|---------------|----------|-----------|-------|------|------|
| Thermal       |          |           |       |      |      |
| conductivity/  | 1        | 15        | 25    | 230  | 270  |
| W/(m·K)       |          |           |       |      |      |

The ceramic substrate can make the temperature of the street lamp only about 60 °C, but the price is much higher than DLC-MCPCB, so DLC-MCPCB is chosen instead of Al-MCPCB. After using DLC-MCPCB, the heat dissipation effect of the street lamp is significantly improved. Not only the chip junction temperature is lower than 72.46 °C, but the temperature difference between the substrate and the thermal grease is only 5.97 °C.
Based on the analysis, on the premise of cost saving and normal operation of LED street lamps, the power of each chip selected is 2 W, and the thermal conductivity of thermal conductive silicone grease is 3W/(m·K). Using DLC-MCPCB instead of Al-MCPCB can effectively reduce the chip temperature and the temperature difference between the substrate and thermal conductive silicone grease. Figure 21 shows that this design also meets the use requirements of other high-power LED street lamps.

When the LED street lamp power is 200 W, the chip temperature is still lower than 100 °C, and the temperature difference between the substrate and the heat transfer adhesive is lower than 10 °C, which has significant heat dissipation performance.
3.3.5. The influence of the radiator. The solid radiator is designed to be hollow and simulated. The results show that the honeycomb type radiator can speed up the heat dissipation (Fig. 22).

Figure. 22 Simulated temperature and heat exchange coefficient of different radiators.

It can be seen from the figure that the three radiators designed in this article can better reduce the chip junction temperature. Due to the different structure, the heat exchange coefficient of the radiator is also different. There is an aluminum plate in the middle of the honeycomb radiator and the fin radiator, which can increase the heat dissipation area. The data shows that their average heat exchange coefficients are 3.98W/(m²·K) and 3.69W/(m²·K) respectively, which are greater than 2.07W/(m²·K)
of traditional radiators. The heat flow distribution of the heat sink with the heat conduction column is the most even. However, the heat dissipation area of the heat conduction column is smaller than that of the aluminum plate, and its fin structure makes the airflow resistance greater, so its average heat exchange coefficient is only 2.77 W/(m²·K). In addition, the heat exchange capacity of the three radiators are 43.80 W, 41.43 W and 42.57 W, which are greater than the 37.97 W of the traditional radiator.

3.4. The final heat dissipation model
The final heat dissipation model uses a honeycomb radiator, and DLC-MCPCB replaces the Al-MCPCB. The power of a single chip is 2 W, and the thermal conductivity of the silicone grease is 3 W/(m·K). Figure 23 is the simulation result of the final heat dissipation model.

![Figure 23](image)

**Figure 23** Heat dissipation effect and surface fluid temperature of the final model.

The results in Figure 23 show that the model can reduce the junction temperature of the chip from 83.93 °C to 65.42 °C. The simulation result of TracePro shows that the luminous flux is 96.78% of the initial luminous flux. While ensuring the optical performance, the heat dissipation effect of the street lamp is improved.

4. Conclusion
The heat dissipation channel of a high-power LED street lamp is studied through experiment and simulation. The data shows that the junction temperature of the street lamp in steady state is 83.93 °C, and the thermal resistance of the LED is 15.06 K/W. And it is found that the aluminum substrate is an important part of affecting heat transfer. Therefore, after analyzing the heat dissipation channel of the street lamp, it is found that changing the arrangement of the chips and the thermal conductivity of the thermal conductive glue can reduce the junction temperature by 7.63 °C and 3.25 °C, respectively. In addition, using DLC-MCPCB instead of Al-MCPCB can reduce the junction temperature by 11.47 °C. Based on these data, we optimize the design of the heat dissipation structure. When the power of single chip is 2 W and the thermal conductivity of silicone grease is 3 W/(m·K), the optimal heat dissipation effect can be obtained by using honeycomb radiator and DLC-MCPCB, and the junction temperature can be controlled below 65.42 °C. Therefore, the experimental data and optimization model in this article can provide a theoretical guidance for practical applications.

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