UDC 628.9

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THE RESEARCH OF THERMAL CHARACTERISTICS OF THE LEDS

To achieve reliability and optimal performance of LED Light sources a proper thermal management design is necessary. Furthermore, some concepts are shown in order to improve the thermal design. The authors have explored a physical phenomenon - the heat flux and temperature, LED lamp cooling system that operates on a heat pipe basis. The paper identifies the basic problem of the measuring heat flow. The general model of the street LED lamp that operates on a consistently and parallel connected thermal resistance basic is showed. The needs established methods of the calculation effective cooling system for outdoor lighting industrial facilities are analyzed. The dependence of the thermal resistance on the ratio of the physical processes is involved in optimizing the thermal regime, such as convection. The relevance of the impact of LED structure on its temperature field. Expressions are obtained for measuring the heat flux density and average integral heat flow. The bulk semiconductor luminaires developed with ribbed radiator, the calculation of which is produced by the known laws of convective heat transfer beam. For all its simplicity and clarity, such an approach is justified only in terms of engineering practice. Giving a fairly simple and feasible solutions for choosing or designing a radiator construction, such a model does not provide a clear understanding of how the convective pass streams, where air pockets occur, affects how the thermal conductivity of the materials used for the heat flow and spreading al.

***Keywords**: LED, convection, thermal resistance, heat flow density.*

Problem statement and analysis of recent scientific research and publications

Applications of LEDs have significantly expanded in recent years. Global trends of LED technology development suggest a steady increase in consumer interest in solid state lighting. Until recently, LEDs were associated mainly with the indication in electronic devices, but now they are widely used in transportation (traffic lights, road signs, and display in stores) as well as in the automotive industry, outdoor city lighting, etc.

Progress in the development of power LEDs has given them an opportunity to hit the lighting area of interest, and soon LEDs will completely replace old-fashioned sources of light [1]. Dependence of parameters of LEDs on the ambient temperature is the subject matter of many scientific articles that address electrical, energetic and colorimetric properties of LEDs, their physical meaning, connection and physical origin (see the examples [2-4]).

With increasing crystal temperature the life expectancy of the LED sharply reduces, so the cooling of the LEDs is still relevant [5-8]. The extraction of heat generated by the LED occurs through the crystall carrier, solder joints, printed circuit board, conductive insulating gasket or conductive paste, body-radiator into the environment. This set of transition resistances on the way "LED - environment" is a major drawback of LED fixtures designs [9]. All the developers of lighting devices try to minimize all resistances whenever possible [10]. In this regard, provision of acceptable thermal conditions is one of the most important requirements for the development of lighting devices using power LEDs.

The purpose and main part

Lamps based on LEDs have high efficiency conversion of electrical energy into light, for this reason the research of energy performance of LEDs is an important task. These characteristics include the light and heat capacity, efficiency and thermal resistance. Their dimensioning is often done by measuring the temperature of various elements of a construction [2,8]. Another important characteristic of LEDs is their longevity [11]. These characteristics are also associated with thermal capacity generated by LED, and thermal resistance of crystal-substrate transfer.

The efficiency of heat release is characterized by such parameters as thermal resistance heat R_o. LED thermal resistance (p-n transition) standard EIA / JEDEC JESD51.1 determines with the equation (1).

$$R_o = (T_J – T_X) / P_{H}, \quad (1)$$

where T_J –p-n transition temperature, T_X – control point defined temperature, P_H – thermal power dissipated by LED.

However, the standard does not provide an explanation of how P_H power is calculated, so in most cases it is calculated as the product of direct voltage applied to the LED, on the LED current ($P_H = U_f \cdot I_f$). However, unlike conventional diodes, LED current component associated with radiating recombination, should be excluded from the P_H calculation [11] for the associated energy is emitted as light. Power converted into heat is the main parameter that is specified in the calculation of thermal modes of LED lights.

It is determined by the difference of consumed electric power of lights and power is converted to light or according to the formula (2).

$$P = \left(1 - \frac{\eta_c}{\eta_{теор}}\right) \cdot P\,, \qquad (2)$$

where P - power consumed by LED system, η_c - LED luminous efficiency, $\eta_{theor.}$ - light radiation efficiency of the LED.

The value of the light emission efficiency $\eta_{theor.}$ can be calculated from the spectral distribution of the LED radiation Figure 1, therefore, in calculation the power is converted into heat taking into account the spectral distribution of radiation of a particular LED.

Correct calculation of the given power gives an opportunity to more accurately calculate the temperature of the body, and thus the p-n transition.

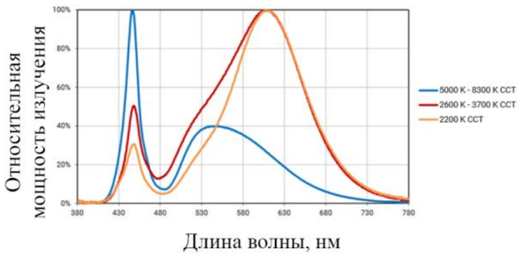

Fig. 1 - The relative spectral distribution of LED Cree radiation XTE, Tcolorful = 6000K.

Power converted into heat is evaluated within 40% - 75% in the literature [3]. Quite often this value is completely neglected. For this case the physical model diagram is shown in Figure 2.

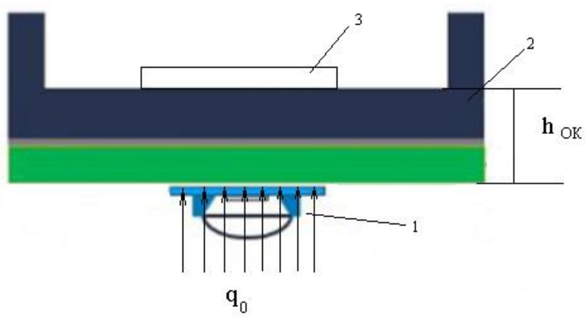

Fig. 2 - Scheme of the physical model of heat transfer in the BOL system and LED surface that is convectively cooled. 1 LED, 2 CO (control object, a printed circuit board, a layer of glue, radiator), 3-BOL)

On the plate surface at z = 0 heat transfer is defined by boundary condition of the second kind (q_0= const), and at z = h_{OK} – the third kind. In addition, the heat transfer coefficient on the entire surface z = h_{OK} and on the front surface of BOL is accepted as the same and constant (α_0= const).

This is consistent with the absence of radial heat losses on the side of the BOL. Thus, on the diagram in Fig. 3 field I corresponds to the tight solid cylinder with the height of h_{OK} and radius r_{bol}; field II - hollow cylinder with the height of h_{OK} with the inner radius r_{bol} and infinite external radius. The surface of the second field at z = 0 receives constant heat flux q_0. On the surface at z = h_{OK} convective heat transfer is running with constant heat transfer coefficient α_0. With this definition of boundary conditions for solving each of the areas the classic method of separation of variables is used, and the distribution of temperature and density of heat flux is presented as infinite series.

Determining coefficients of these series is made based on the values of equality of temperatures T_I and T_{II} and radial heat flow - $\lambda_{OK}\frac{\partial T_I}{\partial r}$ and $-\lambda_{OK}\frac{\partial T_{II}}{\partial r}$ on common boundary areas, that is at r = r_{bol} i $0 \leq z \leq h_{OK}$.

Without BOL the temperature field in the plate is onedimensional and can be considered symmetrical relatively to the axis, and on the convectively cooling plate surface (z = h_{OK}) the temperature is determined by the formula:

$$T\Big|_{z = h_{OK}} = T_{OK} = \frac{q_0}{\alpha_0} + T_{HC}\,. \qquad (3)$$

In the problem assumptions were made about the same heat transfer coefficient of heat flow transducer (hereinafter BOL) to the environment (hereinafter E) on the front and side surfaces of the BOL.

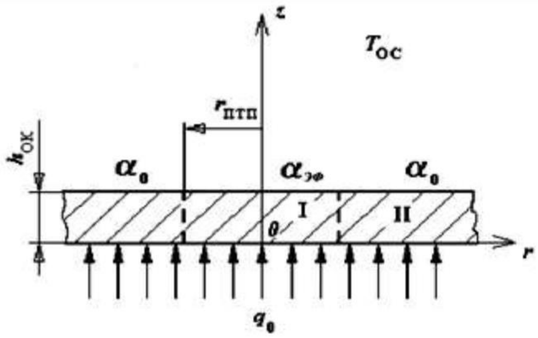

Fig. 3 – Scheme of the transformed problem model

It allowed transforming the original problem by combining thermal resistance of the BOL ($R_{ПТП} = \frac{h_{ПТП}}{\lambda_{ПТП}}$) with a thermal resistance of convective heat transfer at its but end $(\frac{1}{\alpha_0})$ and introducing the concept of efficient heat transfer coefficient $\alpha_{ЕФ} = (\frac{1}{\alpha_0} + \frac{h_{ПТП}}{\lambda_{ПТП}})^{-1}$. In this way the scheme of the original problem model is transformed in the scheme shown in Figure 3

The temperature field is also described by the classical equation of thermal conduction [9] in the cylindrical coordinate system. Given the decision found in accordance with the scheme suggested in [12], the expression for the measured heat flux density and medium density integrated heat flow is:

$$q_{ВИМ} = q_{CP,I}(1,1) = \lambda_{OK} \cdot \frac{T_{OK} - T_{HC}}{h_{OK}} \cdot \left(Bi_{0,h} + 2 \cdot \sum_{n=1}^{\infty} A_n \cdot \frac{h_{OK}}{r_{ПТП}} \cdot I_1(\overline{V_n}) \sin V_v\right) \quad 4)$$

and the heat flux density is determined with the same area on the lower side of a LED:

$$q_0 = \lambda_{OK} \cdot \frac{T_{OK} - T_{HC}}{h_{OK}} \cdot Bi_{0,h}, \quad (5)$$

where $Bi_{0,h}$ – number Bio.

The bulk of the semiconductor luminaries is developed using finned radiators, the calculation of which is made by the known laws of convective heat beam. For all its simplicity and clarity, this approach is justified only in terms of engineering practice. Giving rather simple and real decisions on the choice or design of the radiator, this model gives a clear understanding of how convection currents move, where air pockets occur, how the thermal conductivity of the materials used influences the spreading of heat flow and others. It is therefore necessary to conduct a detailed heat calculation.

Conclusions

Taking into consideration the mentioned above, the importance of analyzing thermal mode of power LEDs is stresses. The correct thermal conditions provide acceptable operating temperature of p-n transition, which will allow operating at high currents, increasing luminous efficiency and minimizing its decline through self heating and, therefore, maximizing the main advantages of semiconductor light sources – durability and efficiency.

The purpose of the further study is to develop the research methods of thermal parameters of LEDs and LED lamps. This assumes the following tasks:

- to develop mathematical models of thermal processes;
- to calculate thermal resistance;
- to conduct experimental studies, compare theory and experiment.

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ДОСЛІДЖЕННЯ ТЕПЛОВИХ ХАРАКТЕРИСТИК СВІТЛОДІОДІВ

А.І. Колесник, Л.А. Назаренко

Аналізується залежність теплового опору від співвідношення фізичних процесів, задіяних в оптимізації теплового режиму, таких як конвекція. Актуальність впливу конструкції світлодіода на його температурне поле. Отримано вираз для виміряної густини теплового потоку та густини середньоінтегрального теплового потоку.

Ключові слова: *світлодіод, конвекція, тепловий опір, густина теплового потоку.*

ИССЛЕДОВАНИЕ ТЕПЛОВЫХ ХАРАКТЕРИСТИК СВЕТОДИОДОВ

А.И. Колесник, Л.А. Назаренко

Анализируется зависимость теплового сопротивления от соотношения физических процессов, задействованных в оптимизации теплового режима, таких как конвекция. Актуальность влияния конструкции светодиода на его температурное поле. Получено выражение для измеренной плотности теплового потока и плотности среднеинтегрального теплового потока.

Ключевые слова: *светодиод, конвекция, тепловое сопротивление, плотность теплового потока.*