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MODELING OF THERMAL CONDITIONS POWERFUL LEDS WORK

Semiconductor lighting engineering is currently one of the priority directions of development of science and technology in most developed countries. LEDs are increasingly being used in a variety of practical applications. These semiconductor light sources have a number of advantages, including energy efficiency, environmental friendliness, compact design and relatively low control voltages to ensure a long service life of the device. The luminous efficiency of LEDs, which is determined through the ratio of the luminous flux emitted by the source to the power consumed by it, is currently about 100-120 Lm/W, which, according to various estimates, is 6-8 times more efficient than that of incandescent lamps and 3-4 times higher than that of a huge number of all kinds of energy-saving lamps. Besides, LEDs have other advantages: rather high mechanical strength and reliability; high level of electrical safety; low level of luminous flux ripple; the possibility of miniature execution; high environmental properties associated with the absence of components containing mercury.

It is known that LED performance is highly temperature dependent. As the temperature rises, the forward voltage of the p-n junction of the LED decreases. If the control device does not reduce the supplied voltage, local overheating will occur, which will lead to the appearance of so-called hot spots, on the printed circuit board. This, in turn, causes a deterioration in performance, and even destruction of the entire circuit due to the acceleration of undesirable physical and chemical processes in the materials and designs of components. The factors listed above lead to the need to establish strict limits on the operating temperature range of elements, create thermal protection circuits and improve methods for heat removal. Therefore, the simulation of the thermal regime is becoming one of the most important stages in the development and design of modem LED arrays [1].

To select the optimal thermal conditions for the LED matrix, physical and mathematical modeling was carried out. The computer implementation of the mathematical model was carried out using the COMSOL Multiphysics software package. The studies were carried out at various values of the current passing through the matrix.

The object of the study was an LED matrix 1.5 Ч 0.6 cm2 in size, located on an aluminum substrate. A general view of the device is shown in Figure 1.

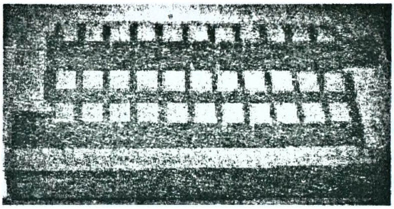

Figure 1 - General view of the LED matrix

Thirty-three Philips Lumileds LXZ1-PE01-0048 LEDs, connected in series, are mounted on the substrate by surface mounting [2]. Note that parallel connection of LEDs is undesirable, as it increases the cost of the product and decreases its efficiency. The LEDs were powered by a constant current in the range from 1 to 1000 mA. To increase the cooling efficiency, the LED matrix was placed in a glass tube with a cooling liquid pumped through it by a pump, which was ethanol [3, p. 178].

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The mathematical model describing the distribution of heat through the elements of the system is based on the heat conduction equation:

$$\rho C_p \frac{\partial T}{\partial t} = k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

where Cp is the heat capacity, p is the density, κ is the thermal conductivity, T is the temperature.

A model of an LED matrix of 33 LEDs with a maximum emission spectrum in the green region of the spectrum (approximately 500 nm) was built in the COMSOL Multiphysics simulation software. When developing the model, the physical properties of all layers of the product were taken into account: aluminum base, copper foil, dielectric, solder and gallium-nitride crystal.

The numerical solution of the mathematical model was obtained by the finite element method [4]. As a result of the calculation, the program gives out the temperature distribution over the elements of the system, which makes it possible to judge the temperature regime of the device and identify its so-called "hot spots".

The thermal distribution was simulated at various values of the LED injection current. Figure 4 shows the dependence of the maximum temperature T in the active region of the LEDs on the thermal power q used to heat the LED crystal, obtained as a result of calculations and experimentally.

Having carried out the selection of the tabular parameters of the layers, the results obtained by the calculation method are quite close to the experimental ones. From a comparison of the graphs built on the basis of the experimental and calculated data, it follows that the dependence are quite close to each other, thus, the use of this software for modeling the thermal mode of LED operation is quite justified. Some discrepancy between the experimental and calculated data can presumably be associated with the heating of LEDs due to radiant heat transfer between them, which will be taken into account in further work on the problem of optimizing the thermal regime of LEDs.

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