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On the thermal characterization of an RGB LED-based white light module

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ABSTRACT

The study aims at evaluating the thermal characteristics of a red-green-blue (RGB) light emitting diode (LED)-based white light module in natural convection through infrared (IR) thermography and forward voltage measurements. The light output and packaging efficiencies of these three color types of LEDs are first characterized using a spherical integrating photometer employing an integrating sphere and an optical analysis program, respectively. These two efficiency data give an estimate of the power fraction not converted into emitting light, by which the temperature distribution of the module is calculated using thermal finite element (FE) modeling. To facilitate the IR thermography measurement, the coefficient of emissivity of the transparent molding compound as the LED optical lens is explored. The results of the measurements are compared with those of the thermal FE modeling and thermocouple measurement. Moreover, the limitation of the IR thermography measurement in LED thermal characterization is addressed, and enhancement of the measurement accuracy is achieved through a proposed temperature correction procedure. Besides, the uncertainty in the forward voltage measurements is also assessed.

Results show that the maximum junction temperature of the RGB LED-based white light module can reach about 100 °C even at a low ambient temperature of 25 °C, and the low thermal conductivity of the transparent molding compound is one of the major causes of the poor thermal performance. In addition, IR thermography tends to overrate the surface temperature of the LEDs, and the transparency of the molding compound could be the direct consequence of the overestimate. It also turns out that the IR thermography can be an effective tool for LED surface temperature measurement after modification using the proposed temperature correction procedure. At last, the uncertainty analysis reveals that the uncertainty in the measured junction temperature using the forward voltage method is about 4–8%, depending on the color of the LEDs, and can it be greatly improved by increasing the accuracy of the voltage measurement.

1. Introduction

Light-emitting diodes (LEDs) are a solid-state lighting technology. It has drawn remarkable attention from the lighting industry in recent years because of their many advantageous features, such as high reliability, long life time, low power consumption, small scale in size…etc. In color performance, they possess the characteristics of wide color gamut and high color saturation. The optical shape of the light emitted from LEDs can be determined by controlling the process of epitaxy and packaging. The increase of the luminous flux or luminance can be feasible by the use of high power and brightness LED chips. To date, for commercial products, the illuminating efficiency for 1 W high power LED has reached above 80 lm/W, which is also far superior to the conventional fluorescent (50 lm/W) and incandescent (20 lm/W) light sources. With the rapid improvement in luminance and efficiency, LEDs are expected to be used as an alternative for the conventional light sources, and has also potential for applications with high commercial value, such as general light source, backlight of liquid crystal display.

Despite of the great improvement in the illuminating efficiency, high percentage of electrical input power in LEDs remains being converted into redundant heat. The problem becomes severe for lighting using high power and brightness LEDs, leading to high chip junction temperature and temperature gradient. High temperature and temperature gradient are essential reliability parameters for LED packages since they potentially create high thermal stresses

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