Enhancement of Heat Dissipation for High Brightness Light Emitting Diodes

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Abstract: A system level thermal management of heat-sink module for power LED is considered in this study. The thermal interface material with aluminum and graphite plate are fabricated and integrated in power LED. The cooling performance of the designed heat-sink modules are demonstrated by measured the light output and the temperature on cathode side of LED. The proposed heat-sink modules demonstrate that a proper thermal management can maintain stable light output and extend system life. Results from experiments also show a large variation in junction temperature and light output among the different heat-sink modules.

Key words: Light emitting diode (LED), heat-sink module, thermal management

INTRODUCTION

Light emitting diode (LED) is a simple junction semiconductor emits continuous light when current flows through its junction at a low voltage. Since the first practical LED was developed in 1962, the LED has proved quite useful as a power-saving device in lighting technology. The major advantages of using LED are low maintenance, low power consumption, small package, long lifetime, high vibration resistance and environmental friendliness (no mercury). Recently, the pioneering work on high brightness LED has led to a movement towards general lighting applications (Steigerwald et al., 2002; Mills, 2004). This reliable light source has also benefited from traffic light industry, vehicle industry and information display technology.

In this study, a system level thermal management for power LED is considered. The thermal interface material with aluminum and graphite plate are fabricated and integrated in power LED. The cooling performance of the designed heat-sink modules are demonstrated by measured the light output and the temperature on cathode side of LED. Therefore, the first objective of the study is to enhancement the heat dissipation for high brightness LED. The second objective is to investigate the relationship between the cathode lead temperature and the light output.

HEAT SINK MODULE

Low LED junction temperature is the key factor to keep a stable light output and an available life of LED for system level application. Thus, better thermal paths are needed to remove the heat from the LED devices. In the following study, the power LED (MPL-73M4W1/65) made by Unity Opto Technology Co. Ltd. is considered. A single power LED is placed on a 1 cm radius substrate of heat-sink module and the structure is shown in Fig. 1 and

Fig. 1: LED heat-sink module

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Fig. 2: Bird view of the LED heat-sink module
Fig. 2. The thickness of the substrate is 1.5 mm, the dielectric thickness is 25–75 μm and the copper thickness is 35–70 μm. Two different materials of aluminum and graphite substrates are fabricated and integrated in power LED.

RESULTS

To understand the effect of the heat-sink module and the light output, a one-watt power white LED that is commonly available in the marketplace is selected. The test devices are shown in Fig. 3, where Fig. 3(a) is the selected power LED and Fig. 3(b) is the fabricated heat-sink module with power LED. In the following experiments, the junction temperature is measured from the cathode lead that is sufficiently close to the junction and where a temperature sensor can be directly attached. The light output is measured by luminous intensity (Lux). The light sensor is located at 20 cm from the test device in black tube, as the experimental setup shown in Fig. 4.

Two heat-sink modules, aluminum-substrate and graphite-substrate, are tested to compare the selected power LED. The LEDs are operated at a fixed voltage of 4 V and the current flows are controlled from 0.3A to 1.25A (i.e., input power from 1.25 to 5 W) under the same ambient temperature room. For each experiment, the cathode lead temperature and the light output are measured after 10 min continuous lighting. Figure 5 shows the measurement results of the cathode lead temperature and the light output as function of the driving current. The results show the average junction temperature on the heat-sink module has 50 degree lower than the power LED in the region of the driving current between 0.3 and 0.6 A. In the same region, the average light output for heat-sink modules has 600 (Lux) higher than the power LED. Between 0.8 and 1.25 A, the heat-sink module provides stable thermal management to maintain light output but the power LED fails to emit light because of the over junction temperature at 0.8 A. Figure 6 shows the results of the heat-sink module with graphite-substrate. The measured junction temperature shows the heat-sink module has average 70 degree lower than the power LED. The light output shows the power LED starts to degrade at the driving current at 0.6 A but the heat-sink module can be over driven to 1 A.

![Fig. 3: (a) Power LED (b) power LED with heat-sink module](image)

![Fig. 4: Experimental setup](image)
CONCLUSIONS

The results of this study show the heat at the p-n junction is the major factors that affect the light output of white LEDs. The proposed heat-sink modules demonstrate that a proper thermal management can maintain stable light output and extend system life. Results from experiments also show a large variation in junction temperature and light output among the different heat-sink modules. As part of on going research, the further investigate using different heat extraction techniques and materials are considered.

REFERENCES