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Advanced thermal enhancement and management of LED packages ☆

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ABSTRACT

Thermal management of packages consists of external cooling mechanisms, heat dissipaters, and thermal interfaces. While keeping cooling condition constant, junction temperature of LEDs with higher thermal resistance increases more rapidly; hence the luminous efficiency decreases more obviously. This paper includes the discussion about the calculation methods of the lighting's heat transfer. The calculation process has been demonstrated by an example of cooling of LEDs lighting in this paper. In particular, the operation package heat transfer enhancement is required by most package manufacturers with a decrease of 20% ~ 30% of the thermal resistance over conventional package geometries.

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1. Introduction

LED ("*L*ight *E*mitting *D*iode"), which are environmental-friendly, power saving and long lasting have caused a revolution in illumination in the 21st century. LED are ideal choices due to their high reliability, low power use, and little-to-no-maintenance needs and are long used in instruments and computers as visual indicators for signal integrity and operations status. High power, high brightness light emitting diodes (LED) are penetrating into a number of lighting applications due to their excellent color saturation and long life characteristics. However, the ability to prevent LEDs from overheating is the most challenging task for thermal designers. Cooling methods and the optical lens are two parameters that play an important role in the success of LEDs.

Therefore, it is critical for maintaining expected LED lifetime and light output, that thermal performance parameters be defined, by design, at the chip package and system level, which includes heat sinking methods and interface materials or methodology. As the LED heat escalates, several key characteristics may become apparent, which demonstrate the importance of LED thermal managements. If the LED thermal management continues to race out of control, the LED junction may break down causing a state of complete thermal runaway.

Heat management is still an important issue for these white high power LEDs. Hu et al. [1] present the thermal and mechanical analysis of high power light emitting diodes with ceramic packages. Higher level of thermo-mechanical stress in the chip was found for LEDs with ceramic packages despite of less mismatching coefficients of thermal expansion comparing with plastic packages. In order not to degrade the LED performance at such a high current operation, Hon et al. [2] study high-power GaN LED chip with low thermal resistance, and proposed a cheaper way to make a high power LED die with lower thermal resistance. A new thermal management application of silicon-based thermoelectric (TE) cooler integrated with high power light emitting diode (LED) is investigated in the study of Liu et al. [3]. The results also show that high power LED integrated with silicon based thermoelectric cooler package can effectively reduce the thermal resistance to zero.

Hwu et al. [4] study on the influences of external and internal thermal resistances of thermal modeling and performance of LED packaging. The study of Chau et al. [5] is to investigate the cooling enhancement design of LED heat sources through an electro- hydrodynamic (EHD) approach, where the forced convection of air is achieved by the ion wind due to gas discharge phenomenon. Biber [6] investigate light emission efficiency of LED as a function of thermal conditions. The paper discusses how to choose the desired operating temperature, by examining the effect of varying the thermal boundary conditions on the light emission. The relationships are important to making design decisions about the LED thermal packaging. A generalized calculation process is given for implementation.

The efficiency and reliability of the solid state lighting devices strongly depend on successful thermal management as Weng [7]. The LED packaging must take the high power density at the LED junction and spread it over a larger area. So, the LED manufacturer must provide the most efficient thermal conduction path possible, while balancing other design factors such as physical dimensions, optical performance and cost.

With the increasing luminous efficacy of LED and the successful fabrication of power high brightness LED chip (HB- LED) solid-state lighting using white HB- LED becomes feasible. LEDs offer long life; durability and high efficiency to the lighting applications but the lifetime of the LEDs products require a proper thermal design. The lifetime of an LED product may be significantly shortened without proper thermal management safeguards in the design. Moreover, a systematic thermal management application of package with high

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Nomenclature

A_i	Surface area of the chip die [m^2]
q	Power dissipation from the chipdie [watt]
T	Temperature [°C]
T_j	Junction temperature of LED chip [°C]
T_{ref}	Reference temperature [°C]
V	Cooling air velocity [m/s]
W	Power [watt]

Greek symbols

θ	Thermal resistance [°C/watt]

Subscripts

a	Ambient
j	Chip junction
ref	reference condition

power light emitting diode (LED) is investigated in present study. An electrical–thermal conversion method is used to estimate the junction temperature of LED. LED diode performance is a function of the device thermal conditions. The forward voltage and light emission of the LED vary with temperature and current. Thermal enhancement package designs for high power LEDs were investigated in this study.

2. Simulation method

A 3-D thermal analysis Fig. 1 was made by steady thermal simulation using the finite element method (FEM) — COMSOL software. This study endeavors to clarify this situation by evaluating the mechanism by which the thermal performance of a LED package. The packages under investigation employ different configuration of GaN based chip, which base on Epistar Corporation AlGaInP series LED chip, test condition, and enhancement design. The feature of LED chip is High luminous intensity, Long operation life, and Low driving current applications. The designs of LED packages resulted in significantly different thermal behaviors. Thermal behaviors, described as thermal resistance, of the three packaging designs were compared and evaluated as functions of bulk thermal resistance, spreading resistance, and surface roughness. It was demonstrated that the junction temperature decreases with the effective contact area ratio in the LED packages.

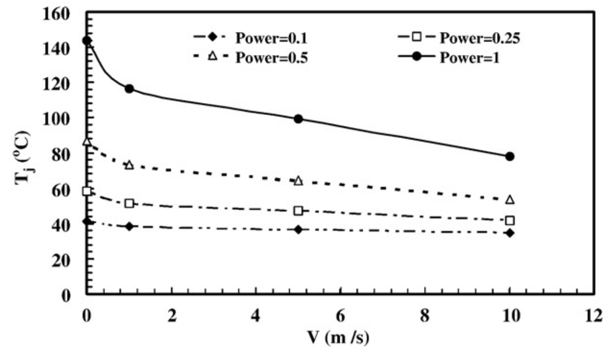

Fig. 2. Comparison of cooling of air velocity effects.

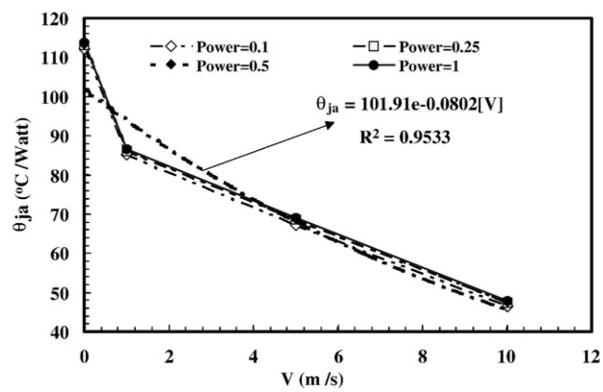

Fig. 3. Comparison of cooling air velocity effects on thermal resistant.

The numerical finite element method model is based on LED package product Everlight Electronics Company Limited. which delivers high luminosity, long operating life and system efficiency in a broad range of designs. Sized in an industry-standard package of Fig. 1, these LEDs are designed to handle higher reflow soldering temperatures and, unlike other packaging methods, their silicon encapsulation prevents accelerated degradation. Fig. 1 also show the three-dimensional mesh model of LED on PCB, which 218545 tetrahedral elements was used in analysis. It is a standard practice to define a lumped junction-to-ambient resistance for a package. For a single chip package, it is fairly simple to define a thermal resistance θ

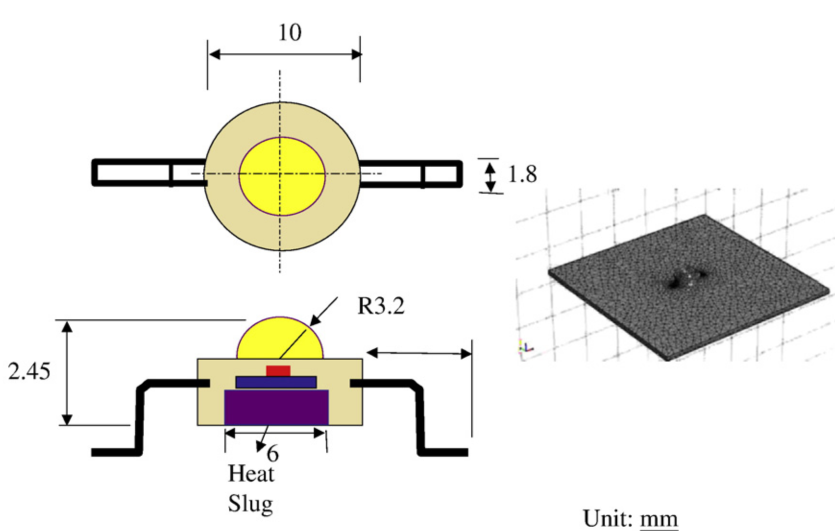

Fig. 1. The specification and physical dimension of LED package.

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