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High Power LED Heat Dissipation Comparison Analysis via Aluminum and Copper Slug

Rajendaran Vairavan[1],Zaliman Sauli[1,a] and Vithyacharan Retnasamy[1]

[1]School of Microelectronic Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Alam, Pauh Putra, Perlis, Malaysia

[a]Corresponding email:zaliman@unimap.edu.my

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Abstract. The vast development of the LED industry has created contemporary set of thermal issues with limits the reliability of the high power LEDs. Thus, this paper reports a simulation analysis done on single chip high power LED package to evalute the effects of heat slug material on the heat dissipation of the LED package. The heat dissipation of two types of heat slug material, aluminum (Al) and copper (Cu) were compared in terms of junction temperature, von Mises stress and thermal resistance of the LED chip at varied input power of 0.1 W and 1W. Results of the analysis showed that the copper heat slug exhibits a better heat dissipation due to its superior thermal conductivity.

Introduction

The evolution of the lighting technology has given birth to the state of the art lighting system which is coherently identified as high power light emitting diodes (LEDs). Over the last five years, the utilization of this solid state lights has increased tremendously in various lighting system which includes electronic displays, traffic signals, automobile headlamps and etc[1]. The vast development of the LED industry has created contemporary set of thermal issues. The augmentation of power density results in elevated junction temperature of the LED chip, which leads to thermal stress condition during operation mode [2]. This significantly affects the reliability of the LED components and the luminous output of the high power LED [3]. Studies are being carried out by various groups of researches to address the thermal challenge faced by the high power LEDs. The thermal performances of high power LED array were appraised by Cheng, Huang and Lin [4] through simulation. In their work, the heat dissipation of high power LED array with multiple fins was scrutinized through simulation using Ansys version 11. the effects of different heat transfer coefficient and fin geometry design on the LED junction temperature were evaluated.Thermal performances of chip-in substrate-type LED package was simulated by Su, Yang, Hung, Lee and Chiang [5]with consideration to the design model of LED packaging, various parameters of chip-in substrate- type structure were scrutinized. The effects of various important parameters of chip-in-substrate-type structures which includes the electro-optical conversion efficiency (eEO), thermal conductivity of filler, thickness of the copper slug, area of the copper slug, and size of the heat sink on the heat dissipation were investigated. Zhang et al. [6] explored the utilization of carbon nano tubes (CNT) for light emitting diode lighting system by simulation. The thermal performance of the LED lighting device was evaluated with varied thermal interface materials (TIMs) and position through simulation. Thus, the thermal challenges faced by the high power LED can be addressed with a proper heat dissipation scheme. Improvising the thermal conduction path through heat lsug material variayion within the LED package can be a method to enhance the reliability and lifetime of the high power LED. Therefore, this paper reports a simulation analysis done on single chip high power LED package. The effects of heat slug material on the heat dissipation of the LED package were evaluated. The heat dissipation of two types of heat slug material, aluminum (Al) and copper (Cu) were compared in terms of junction temperature, von Mises stress and thermal resistance of the LED chip at varied input power of 0.1 W and 1W. The simulation analysis was carried out using Ansys version 11 under natural convection condition with ambient temperature of 25 °C.

Methodology

A single chip high power LED package model was developed in 3D by utilizing Ansys version 11 [7,8]. The LED model comprises of seven components and the dimension of the 3D model is presented in Table 1. The following abbrevation were used to define the dimension in Table 1 where l=length, w = width and h= height and d=diameter. The material properties of the 3D model is stated in Table 2. The simulation was carried out under natural convection condition with ambient temperature of 25 °C . The analysis was executed with two types of heat slug material, namely aluminum(Al) and copper (Cu). The GaN chip was the only plane of heat source with varied input power of 0.1 W and 1W. The other surrounding of the 3D LED model was assumed adiabatic .

Table 1.3D Model Dimension

LED Structure	Dimension (mm)
GaN	l=1, w=1, h=0.25
Sapphire	l=1, w=1, h=0.25
Au–20Sn (Die Attach)	l=1, w=1, h=0.125
Aluminum / Copper (Rectangular Heat slug)	l=5, w=5, h=1
MCPCB	l=8, w=6, h=0.25
TIM	l=8, w=6, h=0.125
Aluminum (Heat sink)	l=20, w=20, h=10.625

Table 2.Material properties

Material	Thermal conductivity k (W/m°C)
GaN	130
Sapphire	42
Au–20Sn (Die Attach)	57
Aluminum(Heat slug)	237
Copper (Heat slug)	401
MCPCB	201
TIM	0.75
Aluminum(Heat sink)	237

The 3D LED model was meshed with 220016 tetrahedral elements with grid independence. The analysis was with varied heat slug material and the junction temperature and von Mises stress of the LED chip were assessed. In addition to that, Equation 1 was used to calculatethe thermal resistance of the single LED chip with varied heat slug materials which is defined as [7,8,]:

$$R_{JA} = \left(\frac{T_J - T_A}{P}\right) \quad (1)$$

Where R_{JA} designated as thermal resistance, T_j is designated as as the junction temperature, T_a is designates as the ambient temperature, P is designates as the input power [9]. Figure 1 illustartes the 3D model of the LED package used in this analysis. The green region in Figure 1 signifies the heat slug which is varied in term of its material in this analysis.

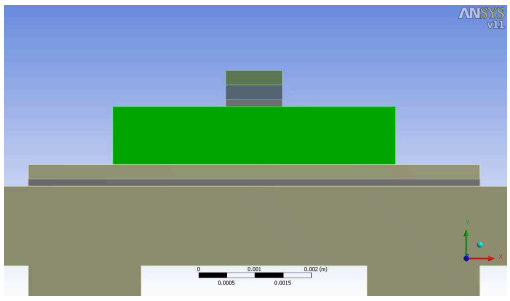

Fig 1. 3D LED Model with varied rectangular heat slug shape

Results and Discussion

In this work, the effects of heat slug material on the heat dissipation of the LED package were evaluated were investigated through simulation. For each heat slug material, the results were compared in terms of junction temperature, von Mises stress and thermal resistance. The simulation was carried out with varied input power of 0.1W and 1 W and the simulated results is shown in Table 3.

Table 3.Simulation Results

Input Power (W)	Junction Temperature (°C)		Von Mises Stress (MPa)		Thermal Resistance (°C/W)	
	Aluminum (Al)	Copper (Cu)	Aluminum (Al)	Copper (Cu)	Aluminum (Al)	Copper (Cu)
0.1	33.79	33.37	35.42	28.07	87.91	83.71
1	112.91	108.71	263.82	212.41	87.91	83.71

In this simulation analysis,two types of heat slug materials; aluminum and copper were utilized to evaluate the effect of heat slug material on the heat dissipation of the single chip LED package. By referring to the simulated results presented in Table 3, According to the results presented in Table 3, the copper heat slug exhibited a improved heat dissipation when compared with the aluminum heat slug. On the other hand, addition, the thermal resistance and the von Mises stress of the LED chip with copper heat slug was lower than the aluminum heat slug. This is due to greater thermal conductivity property of the copper heat slug compared to the aluminum heat slug material. As the thermal conductivity of the heat slug is increased, the heat conduction of the LED package increases. Thus the thermal conductivity of the heat slug significantly influences the thermal performance and the heat dissipation of the LED chip. The influence of the thermal conductivity of a packaging component was justified in the review done by Chang et al [9] where it was stated that the utilization of a higher thermal conductivity material will improvise the thermal condcution path and enhance the heat dissipation of the LED package.

Conclusion

This paper reported a simulation analysis carried out on single chip high power LED package. The effects of heat slug material on the heat dissipation of the LED package were evaluated. The heat dissipation of two types of heat slug material, aluminum (Al) and copper (Cu) were compared in terms of junction temperature, von Mises stress and thermal resistance of u)the LED chip at varied input power of 0.1 W and 1W. The simulation analysis was carried out using Ansys version 11 under natural convection condition with ambient temperature of 25 °C. The key findings of this analysis showed that a higher thermal conductivity of the slug material, in this case, the copper heat slug significantly enhances the heat dissipation of the LED package.

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