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LED Heat Dissipation Study Using Different Cu Slug Size

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A B S T R A C T

High power light emitting diodes (LEDs) have significant contribution in illumination industry due exceptional advantages in terms of low power consumption, superior reliability, prolonged life time and high efficiency. Rapid growth of the LEDs industry has generated a fresh set of thermal challenges which requires immediate attention. This paper presents a simulation work on a single chip high power LED package. This work focuses on the evaluation of the junction temperature and LED chip stress with varied copper rectangular heat slug size under natural convection condition at ambient temperature of 25°C. Ansys version 11 was used for the simulation. The single chip was powered with input power of 0.1 W and 1W respectively. Results exhibited that the heat slug size has significant effect on the junction temperature of the LED.

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INTRODUCTION

The light emitting diode industry is heading towards a rapid growth in terms of illumination application. However, this tremendous advancement has generated a fresh set of challenge which requires immediate attention and cost effective solution. During operation mode, thermal stress condition occurs due to the increase in power density of the LED device which significantly influences the life time and luminous efficacy of the high power LED [1].The luminous flux and chromaticity proportion of the spectral response are significantly responsive and altered to the operating temperature of the LED. Therefore, to enhance the performance of the LED and to reduce the cost of production, the critical interaction among optical, thermal and electrical parameters are being investigated by various researches which are categorized in two part, namely electrical based parameters and physical package design [1]. K. Hyunjong, K. Kyoung Joon, and L. Yeonwon [2] reported on thermal performance of high power LED with smart heat sinks (SHSs) with hybrid pin fins (HPFs) comprising of internal channels and integrated plate fins. Perpina et al. [3] reported a study on the thermal scrutinization of an LED driver board on solid state ligthing. Infrared thermography and thermocouple at detailed location were monitored to observe the thermal effects on LED driver board. Teeba et al. [4] performed an evaluation on thermal resistance and junction temperature variation on green and white based LEDs. Thermal transient method was used to measure the variation and the effect of input power augmentation on the heat flow was examined. Shaojie, Qiang, Minghua, Xiaoqing, and Jianyi [5] evaluated the thermal spreading effect on flip chip and face-up chip LED to optimize the package design. Thermal simulation and thermal spreading were calculated for the optimization process.Andonova, Yordanov, and Yordanova [6] investigated the thermal stability of LED lighting package via lifetime accelerated test. Three different LED lighting structures were examined at varied temperature levels.Accordingly, as exhibited by the work of various researches, thermal management is very significant to control the operating temperature of the LEDs. With an efficient thermal management, the efficiency and the reliability of high power LED can be prolonged [7-9]. The heat generated by the high power LED has to be dissipated through suitable thermal path within the package. Nevertheless, to develop and enhance the thermal path within a package through direct experimental method is costly and timing consuming as it involves various testing stage and design variation due to the abundant components and materials involved within the packaged LED [1-10]. Thus, this can be overcome by utilizing simulation method as unlimited number of testing in term of

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heat dissipation and improvement on the LED package in terms of structural and material variation can be done before finalizing the actual device itself which is cost effective [7-9].Thus, this paper presents a simulation work on a single chip high power LED package. This work focuses on the evaluation of the junction temperature and LED chip stress with varied copper rectangular heat slug size under natural convection condition, h= 5 W/m2C. Ansys version 11 was used to perform the simulation [7-9]. The single chip was powered with input power of 0.1 W and 1W respectively. The simulation was done at ambient temperature of 25°C. The results were evaluated in term of junction temperature, LED chip Von Mises stress and thermal resistance.

Methodology:

Ansys version 11 was used for the simulation. The analysis was carried out in two parts. The first part is thermal analysis. The LED model was designed in 3D with (SOLID 87) element [7-9]. The contact region between the LED components comprises of (CONTA174) and (TARGE170) element. The 3D LED model with consisted of 229302 tetrahedral elements and 220016 element with grid independence for each respective LED model with varied heat slug , R1 and R2. The R1 and R2 abbreviation denotes size of the varied rectangular heat slug of l=1mm, w=1mm, h=1mm and l=5mm, w=5mm ,h= 1mm respectively. The second part is the stress analysis. (SOLID 187) element was utilized in this part of the analysis for the LED model development [7-9]. The contact region of the model comprized of (CONTA174) and (TARGE170) element. For the stress analysis, the simulated junction temperature attained from the thermal analysis was utilized as an input to compute the stress of the LED chip. Both analysis were carried out under natural convection condition of h= 5 W/m^2C at ambient temperature of 25°C. Respective input power of 0.1 W and 1W were applied to the LED chip. End time of 10000s was set for both analysis to attain steady state in the output result. Thermal resistance of the LED was calculated through equation1:[10]

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

R_{JA} is thermal resistance, T_j is junction temperature, T_a is ambient temperature and P is input power[10]. In addition, the simulation was also conducted based on the Fourier's law of heat conduction and Newton Law of cooling. The Fourier's law of heat conduction is stated as [11]:

$$Q_T = \frac{k_w}{y_w} A_T (T_1 - T_2) \quad (2)$$

where Q_t is the total quantity of heat transferred per unit time, k_w is the thermal conductivity of the wall material, y_w is the wall thickness, A_T is the total area of the wall and T_1 ,T_2 is the temperature of hot and cold surfaces of the wall respectively.The Newton Law of cooling is stated as[11]:

$$Q_{conv} = h\, A\, \Delta T \quad (3)$$

where Q_{conv} is the amount of heat transferred through convection (W); h is the heat transfer coefficient (W/m^2K); A is surface area (m^2);ΔT is temperature gradient across the material (°C) which is the difference between the surface temperature and ambient air temperature.

Simulation analysis was simplified with few assumptions. First, each material and its parameter are temperature independent from 25 °C to 150°C. Second, all the interface between the material are perfect. Third, bonded wires and LED encapsulant are neglected for simplified 3D modeling process. Fourth, only conduction and convection condition exist while radiation effect were ignored. Fifth , 80% of the input power is converted into heat and is transfered into the package with LED chip as the sole heat source. The simulation was carried out with two 3D LED package model designed with varied copper rectangular heat slug size, R1 and R2 where R1 and R2 is acronym denotes the heat slug with varied size of The basic structure of the 3D LED package comprises of single GaN LED chip with dimension of l=1, w=1, h=0.25, attached to sapphire substrate with dimension of l=1, w=1, h=0.25, die attach with dimension l=1, w=1, h=0.125 ,copper based rectangular heat slug with varied size l=1 mm, w=1 mm ,h= 1 mm and l=5 mm, w=5 mm ,h= 1 mm respectively., metal core printed circuit board with dimension l=8, w=6, h=0.25, thermal interface material with l=8, w=6, h=0.125 and aluminum heat sink with four fins with dimension of l=20, w=20, h=10.625 where l=length, w = width and h= height. Table I demonstrates the material properties of each component of the LED package.

Table 1: Material Properties

Material	Thermal conductivity,k (W/m°C)
GaN	130
Sapphire	42
Au–20Sn (Die Attach)	57
Copper (Heat slug) (R1 and R2)	401
MCPCB	201

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TIM	0.75
Aluminum (Heat sink)	237

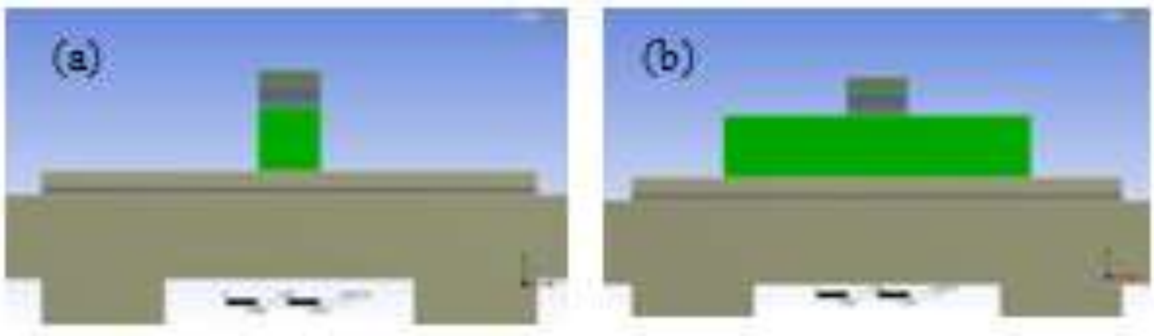

Fig. 1: 3D Single Chip LED model with varied heat slug (green region); (a) R1 (b) R2

RESULT AND DISCUSSION

A simulation work on a single chip high power LED package was performed. This work focuses on the evaluation of the junction temperature and LED chip stress with varied copper rectangular heat slug size under natural convection condition, h= 5 W/m2C. Simulation was done through Ansys version 11 [7-9]. The single chip was powered with input power of 0.1 W and 1W respectively. The simulation was done at ambient temperature of 25°C. The results were evaluted in term of junction temperature, LED chip Von Mises stress and thermal resistance. The junction temperature curve of the LED package with varied heat slug size at input power of 0.1 W and 1W is elucidated in Fig. 2. The solid blue line indicates the LED package with R1 heat slug with junction temperature of 34.08°C and 115.81°C at input power of 0.1W and 1W. As for the LED package with R2 heat slug, the red solid line in Fig.2 indicates the junction temperature of 33.37°C and 108.71°C at input power of 0.1 W and 1W.Fig.3 exhibits the Von Mises stress of the LED chip with varied heat slug size at input power of 0.1 W and 1W. The solid blue line indicates the LED package with R1 heat slug with Von Mises stress of 29.93MPa and 221.56MPa at corresponding input power of 0.1 W and 1W. As for the LED package with R2 heat slug, the red solid line in Fig.3 indicates Von Mises stress of 28.07MPa and 212.41Mpa at input power of 0.1 W and 1W. Equation (1) was used to calculate the thermal resistance of the LED package and the result is shown in Table II. For both input power, the thermal resistance of the LED package with R1 heat slug was 90.81°C/W and 83.71°C/W for the LED package with R2 heat slug.

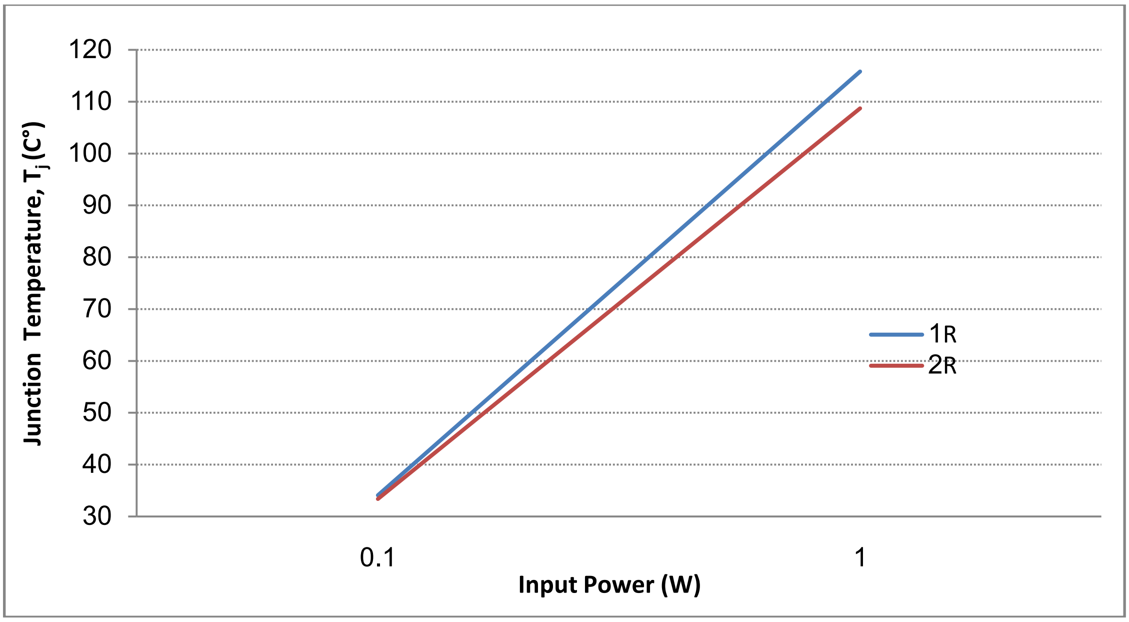

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Fig. 2: Junction temperature of the LED package with varied heat slug size at input power of 0.1 W and 1W

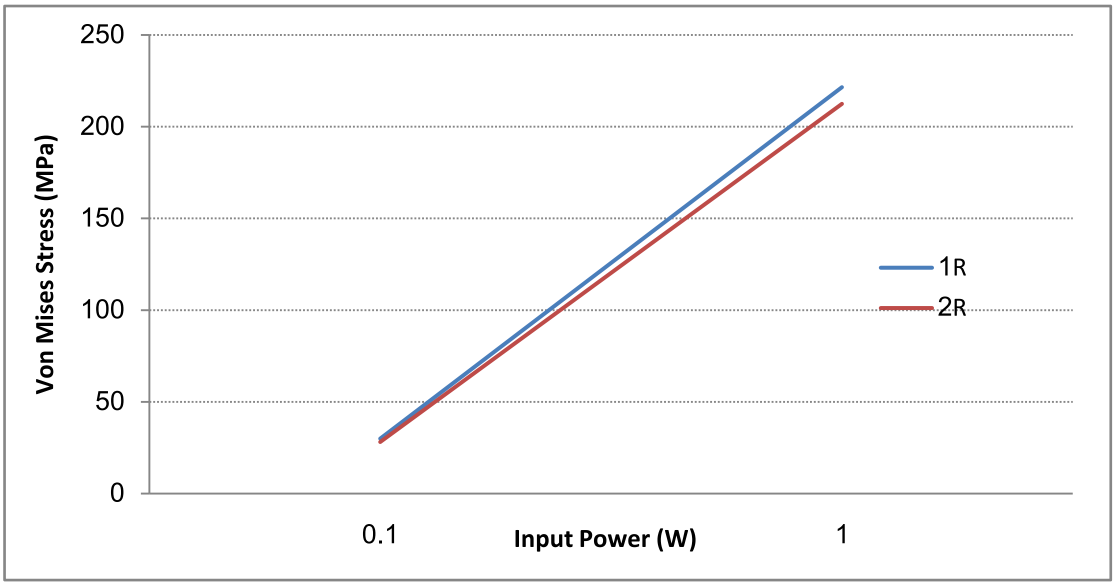

Fig. 3: The Von Mises stress of the LED chip with varied heat slug size at input power of 0.1 W and 1W

Table 2: Thermal Resistance Result

Heat Slug	Thermal Resistance (°C/W)
R1	90.81
R2	83.71

In overall, the simulated results showed that the heat the LED package with R2 heat slug exhibited a superior heat dissipation contrast to the LED package with R1 heat slug. A junction temperature difference of 7.1°C was demonstrated between the two LED packages with varied heat slug for an input power of 1W. On the other hand, the the LED chip with R2 heat slug had a lower Von Mises. stress of compared to the LED chip with R1 heat slug. The stress difference between both heat slugs sizes were 9.15 MPa. As a result, a larger slug size inside the LED package compliments for enhanced heat dissipation. Additionally, the Von Mises stress and the thermal resistance of the LED chip decreases the increase of heat slug surface area. Chang, Das, Varde and Pecht [12] expressed that the surface area of the heat slug has a significant effect on the heat dissipation and junction temperature of the LED chip. Their review paper acknowledged the heat dissipation of the LED package can be improved with a larger heat slug size. In addition, the observation of junction temperature reduction is also justified justified by the Fourier's law of heat conduction equation (Equation 2) and Newton Law of cooling (Equation 3). As the total area, A_T of the heat slug is increased, the the junction temperature of the LED chip is reduced[11]. Thus, a decrease in junction temperature was demonstrated, when the surface area of the heat slug was increased. This is due to the exposed surface are of the heat slug which enables individual particle from the surrounding air to act on the surface of the LED package and the heat conduction process takes place. Hence, as the heat slug size is increased, an wider area with more surface particles exist for a better heat conduction. Therefore, the heat transfer is correlated to the surface area of the heat slug which significantly influences the operating junction temperature and the stress of the LED chip during operation mode.

Conclusion:

A simulation work on a single chip high power LED package was presented. The focus of the work is on the evaluation of the junction temperature and LED chip stress with varied copper rectangular heat slug size under natural convection condition, h= 5 W/m2C at ambient temperature of 25°C.Simulation was carried out using Ansys version 11. The single chip was powered with input power of 0.1 W and 1W respectively. The results were evaluted in terms of junction temperature, LED chip Von Mises stress and thermal resistance. Result showed reduction in the junction temperature and Von Mises stress of the LED chip when a larger heat slug size is used.

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REFERENCES

[1] Negrea, C., P. Svasta, and M. Rangu, 2012. "Electro-thermal modeling of power LED using SPICE circuit solver," in Electronics Technology (ISSE), 2012 35th International Spring Seminar on, pp: 329-334.

[2] Hyunjong, K., K. Kyoung Joon, and L. Yeonwon, 2012. "Thermal performance of smart heat sinks for cooling high power LED modules," in *Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), 2012 13th IEEE Intersociety Conference on*, pp: 962-967.

[3] Perpina, X., R.J. Werkhoven, M. Vellvehi, X. Jorda, J.M.G. Kunen, J. Jakovenko, P. Bancken, and P.J. Bolt, 2012. "LED driver thermal design considerations for solid-state lighting technologies," in *Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems (EuroSimE), 2012 13th International Conference on*, pp: 1/5-5/5.

[4] Teeba, N., L. Kean Yew, L.C. Keng, P. Anithambigai, K. Dinash, and D. Mutharasu, 2011. "Study on the variation in thermal resistance and junction temperature of GaN based LEDs using thermal transient measurement," in *Quality Electronic Design (ASQED), 2011 3rd Asia Symposium on*, pp: 310-314.

[5] Shaojie, D., Z. Qiang, W. Minghua, J. Xiaoqing, and Y. Jianyi, 2011."Analysis of thermal spreading resistance in high power LED package and its design optimization," in *Electronic Packaging Technology and High Density Packaging (ICEPT-HDP), 2011 12th International Conference on*, pp: 1-5.

[6] Andonova, A., R. Yordanov and I. Yordanova, 2011. "Thermal stability analysis of power LED during aging," in *Electronics Technology (ISSE), 2011 34th International Spring Seminar on*, pp: 274-278.

[7] Vairavan, R., Z. Sauli, V. Retnasamy, R. C. Ismail, N.I.M. Nor, N.S. Nadzri, and H. Kamarudin, 2013. "High Power LED Thermal and Stress Simulation on Copper Slug," in *Computer Modelling and Simulation (UKSim), 2013 UKSim 15th International Conference on*, pp: 294-298.

[8] Sauli, Z., V. Retnasamy, R. Vairavan, R.C. Ismail, N. Khalid, M.F.C. Husin and H. Kamarudin, 2013. "Stress and Temperature Simulation Using Copper-Diamond Composite Slug," in *Computer Modelling and Simulation (UKSim), 2013 UKSim 15th International Conference on*, pp: 299-303.

[9] Sauli, Z., V. Retnasamy, R. Vairavan, W.M.W.N. Haimi, H. Kamarudin, Y. Neoh Fung, and N. Khalid, 2013. "Solid State Lighting Stress and Junction Temperature Evaluation on Operating Power," in *Computer Modelling and Simulation (UKSim), 2013 UKSim 15th International Conference on*, pp: 290-293.

[10] Shin, M.W. and S.H. Jang, 2012. "Thermal analysis of high power LED packages under the alternating current operation," Solid-State Electronics, 68: 48-50.

[11] Butterworth, D., 1977. ”Introduction to heat transfer” (Vol. 18). Oxford University Press for the Design Council, the British Standards Institution and the Council of Engineering Institutions

[12] Chang, M.-H., D. Das, P.V. Varde and M. Pecht, 2012. "Light emitting diodes reliability review," *Microelectronics Reliability*, 52: 762-782.