Effect of Deficient Thermal Grease on the Junction Temperature of LEDs Package

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Abstract: This work is related to the study of the effect of a deficient thermal interface material (TIM) on the thermal properties of LEDs package under natural convection. The used package is composed of 36 LEDs on rectangular fin heat sink. Numerical modeling using COMSOL Multiphysics® simulation software has been developed. We demonstrated that a thicker air layer, between the thermal grease and the heat sink, participates severely in the junction temperature rise.

Keywords: Deficient thermal grease, air layer thickness, junction temperature, heat sink average temperature.

1. Introduction

Recently, interest in the use of light emitting diodes (LED) for general lighting has been steadily on the rise. In fact, LED has several advantages such as longer lifespan (100000 hours), lower energy consumption, higher luminous efficiency and more durable structure compared to other light sources [1]. However, the use of LEDs presents thermal problem. In fact, 70% of their total power consumption is converted to heat, which increases severely the p-n junction temperature. This will reduce significantly the lifetime of the LEDs and may cause the failure of the light source. Keeping the p-n junction temperature as low as possible is crucial to provide more reliable lighting system. Air-cooling is one of the most interesting methods for exchanging heat with ambient [2-6]. Nevertheless, it is also important to control the path between heat sink and LED to ensure the maximum heat transfer rate.

In this study, our aim is to study numerically the effect of deficient path between heat sink and LED trough introducing an air layer between heat sink and thermal grease.

3. Numerical modeling

3.1 Geometry and general assumptions

In this work, a LED package is numerically involved. It is composed of 36 LEDs mounted on an aluminum rectangular fin heat sink by thermal grease. To investigate the effect of deficient thermal grease, we imposed a thin air layer between heat sink and TIM as it is shown in Figure1. Majority of materials properties are from COMSOL material library. For the numerical study, the computational domain is limited to the quarter of the LED package, as it is illustrated in Figure2, since the model geometry is symmetric.

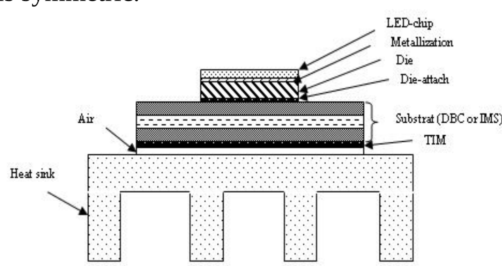

Figure 1. One LED package with deficient TIM

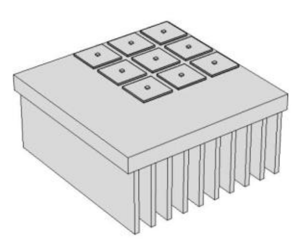

Figure 2. Computational domain

3.2 Governing equation and boundary conditions

The governing equation for this study is the energy equation at the steady state:

$$\nabla.(k\nabla T) = 0$$

Were k is thermal conductivity *[W/m.K]* and T is temperature *[K]*.
To solve this equation, we simply used heat transfer module provided by COMSOL Multiphysics®. In this module, all types of boundary conditions are provided.
We imposed a heat flux on the bottom of LEDs (1W per LED). The heat sink is cooling by natural convection. So, we used 'convective cooling' in the COMSOL® interface, and we imposed a constant convective coefficient $h=5[W/m^2.K]$. All exterior surfaces of LEDs: substrate, die attach, die… are supposed adiabatic.
The mesh was refined to test the convergence using physics controlled mesh provided by COMSOL®.

4. Results and discussions

4.1 LEDs package with perfect thermal grease

The temperature profile of LEDs package having good thermal grease is shown in Figure 3. Junction temperature is about 70 ˚C thanks to the good heat transfer by natural convection, since the contact between LED and heat sink is perfect.

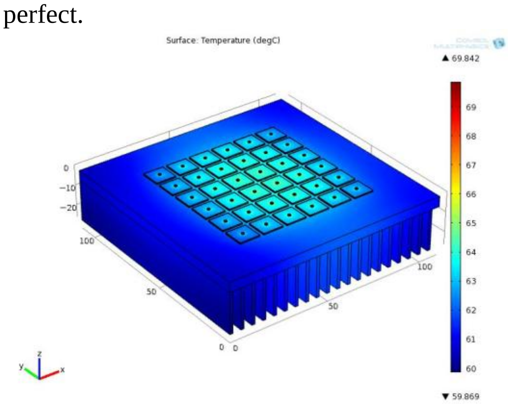

Figure 3. Temperature profile on LEDs package wit perfect TIM

4.2 Effect of deficient thermal grease

The effect of the air layer thickness on junction temperature and heat sink average temperature is conducted in Figure 4. A higher junction temperature resulted from a thicker air layer, since this decreases heat transfer rate between lamp and radiator. In fact, due to the lower thermal conductivity of air *0.026[W/mK]*, heat is not properly transmitted to the radiator and is imprisoned in the lamp. This participates in the junction temperature rise.
However, the deficient thermal grease has no effect on the heat sink average temperature. In fact, this temperature is constant when increasing the air layer thickness between heat sink and lamp.

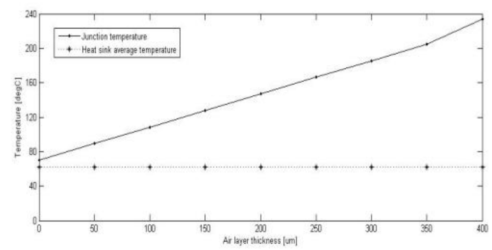

Figure 4. Effect of deficient TIM on temperature rise

4.3 Comparison between perfect and deficient thermal grease

The effect of deficient thermal grease is remarkable on the junction temperature rise. In fact, with a 100µm air layer, the junction temperature increases by 55%. Deficient TIM affects also the substrate temperature, which increases by 58% when having a 100µm air layer. Figure5 illustrates the difference between substrate temperatures for a perfect and deficient TIM (100µm air layer). However, this effect is not significant on the heat sink base temperature. In fact, the temperature profile is the same for the two cases.

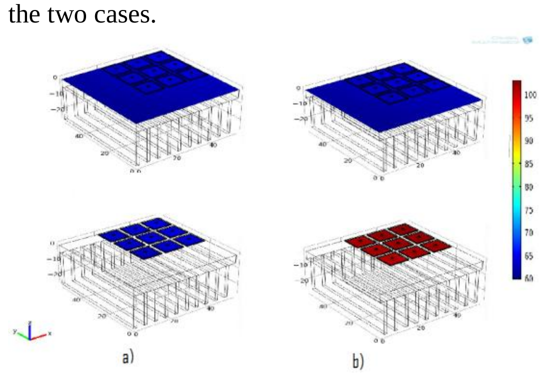

Figure 5. Temperature profile on substrate and heat sink base: a) with perfect TIM b) with deficient TIM

5. Conclusions

In conclusion, an efficient heat sink design is required to enhance the heat transfer rate, reduce the junction temperature and provide the LED performance. But alone, it is not sufficient to solve the thermal problem of LED. In fact, this study shows that a bad contact between thermal grease and heat sink can produce air layer and increase widely junction temperature. So, for a better thermal management, it is required to control the path between the heat sink and the lamp to ensure a maximum heat transfer rate and guarantee longer LED lifespan.

6. References

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