Thermal Measurement Guidelines for SSL LEDs

Introduction

One of the most critical design parameters in an LED illumination system is the systems ability to draw heat away from the LED package. High operating temperatures at the LED junction adversely affect the performance of the LED resulting in color shifts and decreased light output and lifetime for the LED package. Therefore, monitoring the LED junction temperature is paramount for the overall system performance. Unlike LED drive current and forward voltage that can be measured easily, LED junction temperature cannot be measured directly, and must be calculated. This document will provide guidelines for measuring the solder point temperatures and calculating the approximate junction temperature for various LEDs from OSRAM Opto Semiconductors which are used in Solid State Lighting (SSL) applications.

Leadframe Packages

Two OSRAM LEDs used for various SSL applications with leadframe packages are the Advanced Power TOPLED Plus and the DRAGON® product family (Golden DRAGON®, Golden DRAGON® Plus, and Golden DRAGON® Oval Plus). **Figure 1** shows the basic internal construction of the Advanced Power TOPLED Plus LED.

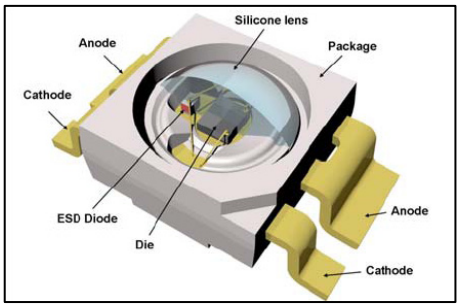

Figure 1: Internal Construction of Advanced Power TOPLED Plus LED

Within the housing, the semiconductor chip and the ESD diode are mounted to the wider leads of the package and make contact with the other side by means of wire bonding. In addition to providing mounting and electrical connection of the LED to the circuit board, the wider leads of the package also serve to dissipate the heat that arises during the operation of the LED. The Advanced Power TOPLED Plus has a typical thermal resistance of 40 K/W from junction to solder point. To measure the solder point temperature of the Advanced Power TOPLED Plus, the thermocouple is attached to the wider lead of the LED package. **Figure 2** shows the thermocouple attach position.

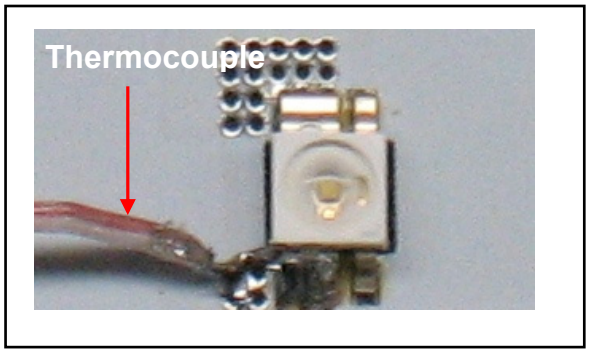

Figure 2: Thermocouple attach position for the Advanced Power TOPLED Plus LED

Information about measurement procedures, the thermocouples used and their systematic errors as well as the ways in which thermocouples are mounted can be found in the application note “Temperature Measurement with Thermocouples.”

The basic equation governing the calculation of junction temperature of the LED on measuring the solder point temperature is defined below:

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Tj = Ts + RthJS * PD …… (1)
Where:
Tj = Junction Temperature of the LED
Ts = Solder Point Temperature of the LED
RthJS = Thermal resistance from junction to solder point.
PD = Heat Dissipated across the LED

The DRAGON product family is based on a thermally optimized package design consisting of the semiconductor chip directly mounted on an integrated heat sink that acts as a heat spreader in a prefabricated plastic housing with connection contacts. The DRAGON product family yields a typical thermal resistance of 6.5 K/W from junction to solder point. **Figure 3** shows the internal construction of the DRAGON products and the primary path of heat transfer.

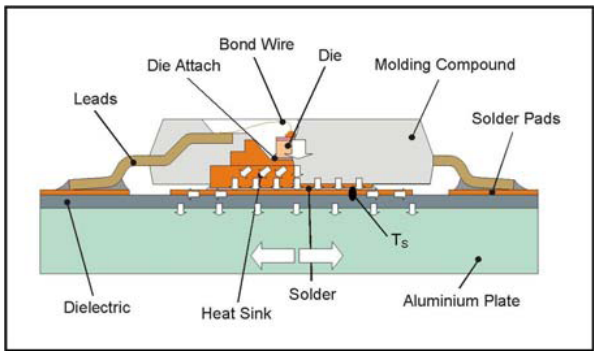

Figure 3: Internal construction of the DRAGON products and primary path of heat transfer

It is recommended to record the temperature directly adjacent to the DRAGON housing on the long side of the package by means of a thermo element on the circuit board. Steady state temperature gradient to the heat sink is negligible in this case.

The solder mask (if present) should be removed to solder the thermocouple to the circuit board. **Figure 4** shows the thermocouple attach position.

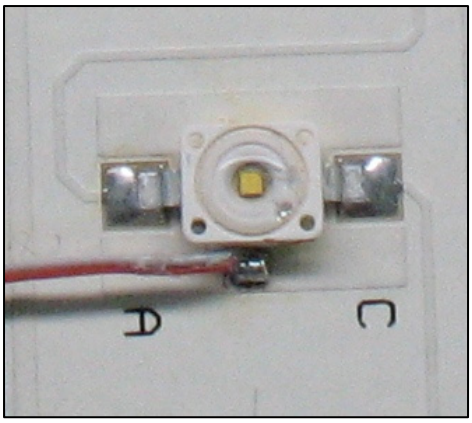

Figure 4: Thermocouple attach position for the Golden DRAGON Plus LED

Ceramic Package

The OSLON SSL is a compact power LED in a ceramic housing used for various SSL applications. The internal construction of the OSLON SSL LED consists of a semiconductor chip mounted on a ceramic carrier and overmolded silicone lens. The thermal pad is electrically isolated from anode and cathode pads. The OSLON SSL has a typical thermal resistance of 7 K/W from junction to solder point and a maximum thermal resistance of 9.4 K/W. **Figure 5** shows the package and the pad layout of the OSLON SSL package.

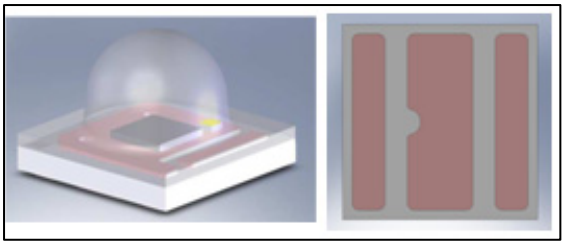

Figure 5: Package and the pad layout of the OSLON SSL

The ceramic package with the three pads provides an effective channel for the heat transfer for the die. The thermocouple should be attached as close as possible to the package to measure the solder point temperature. When mounted on a printed circuit board the pads are not easily accessible for

attaching a thermocouple. One way to get around this problem is to extend the copper area for the thermal pad and place the thermocouple attach on this copper area. **Figure 6** shows recommended copper area for OSLON SSL solder pad layout. The extended copper around the thermal pad could be used to attach the thermocouple.

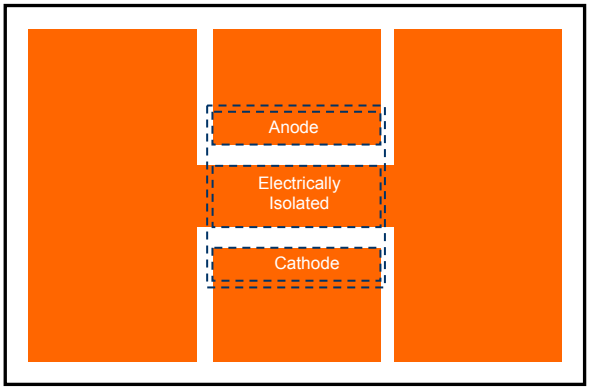

Figure 6: Recommended copper pad area for heat spreading and thermocouple attach

Again, the solder mask (if present) should be removed to solder the thermocouple attach to the circuit board.

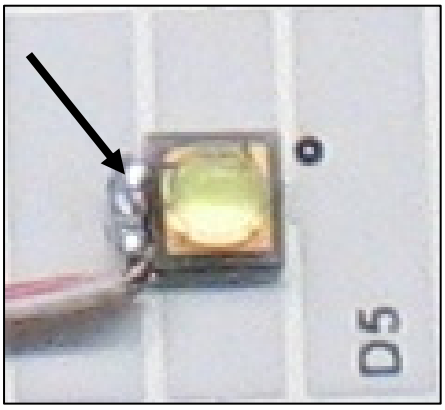

Figure 7: Thermocouple attach position for the OSLON LED

Thermal Resistance Substrate Technologies (thermocouple attach to solder point):

The OSLON SSL can be mounted on two-layer FR4, multi-layer FR4 or MCPCB (metal core printed circuit board). To ensure optimal operation, the thermal resistance path between the LED and the ambient should be as low as feasible. An FR4 board — although cost effective — has very low thermal conductivity as compared to a MCPCB. When using a thermocouple to measure the solder point temperature, the thermocouple is fixed directly along the ceramic housing of the OSLON SSL package on the thermal pad. However, to get a useable result the temperature gap between the solder pad temperature and the reading point has to be considered for the calculation of the junction temperature. This operation-related correlation factor is defined as the thermal resistance between the thermocouple attach and the solder point ($R_{th,S-TC}$). With this factor taken into consideration, the equation for calculating junction temperature of the LED is:

$$T_j = (R_{thJS} + R_{thS-TC}) * P_D + T_{TC} \quad \text{..... (2)}$$

Where
T_j = Junction Temperature of the LED
R_{thJS} = Thermal resistance from junction to solder point
R_{thS-TC} = Thermal resistance from thermocouple attach to solder point
P_D = Heat Dissipated across the LED
T_{TC} = Temperature at thermocouple attach

In order to show the thermal performance of the OSLON SSL LED on MCPCB and FR4 MCPCB (laminated) the method of numerical analysis is used. The goal of the analysis is comparison under the same environmental conditions.

The geometry and material data as well as the standard boundary conditions are listed in the following table:

Component	OSLON SSL
PCB Dimensions	25.4 x 25.4 mm^2
Power Dissipation	1W
Ambient Temperature	25˚C
Material for solder pads	35µm copper
Heat Sink (aluminum)	50.8 x 50.8 mm^2
Board Materials	FR4 MCPCB

Thermal Analysis

For MCPCB the dielectric used has a thermal conductivity of 1.3 W/m-K and a thickness of 75 µm. The maximum thermal resistance of 9.4 K/W (RthJS) for the OSLON SSL LED is considered for the analysis. **Figure 8** shows the setup of OSLON SSL LED on a MCPCB on a heat sink.

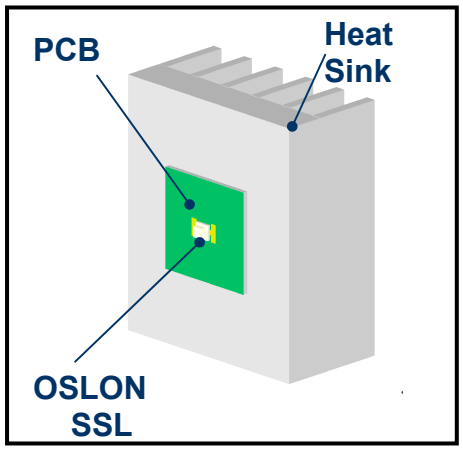

Figure 8: Setup for thermal analysis

Figure 9 shows the thermocouple attach point on the extended thermal pad of the OSLON SSL LED.

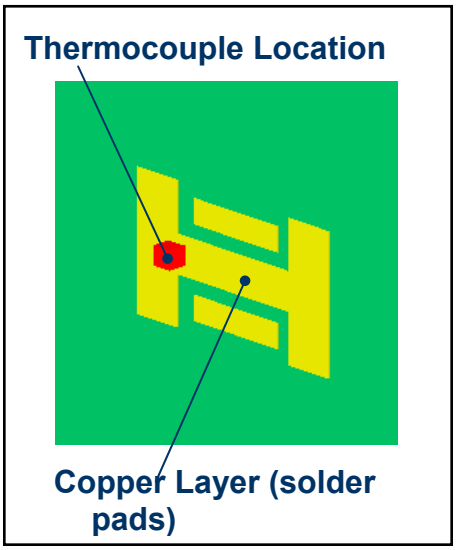

Figure 9: Shows the thermocouple attach position on the PCB

Figure 10 shows the temperatures at various points (junction, solder point and thermocouple attach points) for this analysis.

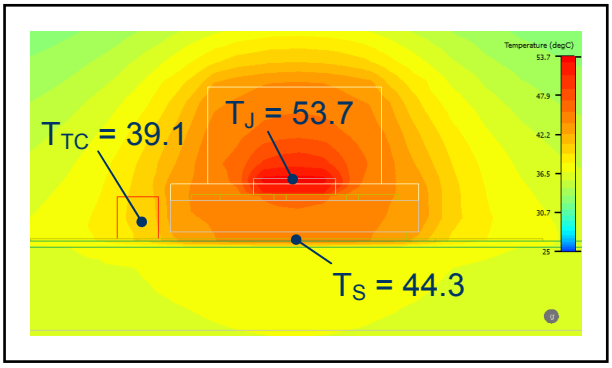

Figure 10: MCPCB with Dielectric (λ = 1.3 W/m-K)

Substituting the values for various temperatures, thermal resistance and heat dissipated in Equation (2) for a MCPCB the thermal resistance from solder point to thermocouple; RthS-TC contributes ~ 5 K/W.

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A similar analysis with the same boundary conditions was performed with a FR4 dielectric.

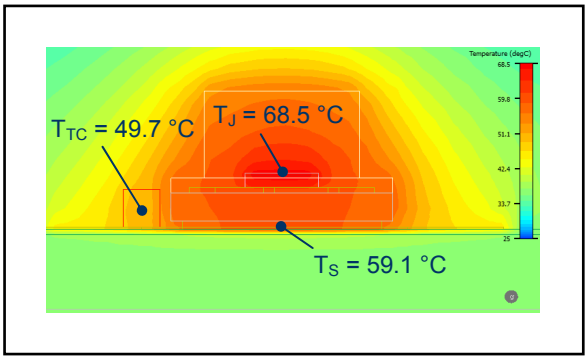

Figure 11: FR4 PCB glued on aluminium

Substituting the values in Equation (2) for a FR4 dielectric RthS-TC contributes ~ 10 K/W.
These results indicate that the additional thermal resistance from solder point to thermocouple attach point needs to be considered to calculate the accurate junction temperature of the OSLON SSL LED based on the substrate technology employed.

Conclusion

The document provides guidelines for the thermocouple attach to measure the solder point temperature for various SSL LEDs. Also, it describes the thermal resistance between the thermocouple attach point and the solder point for the OSLON SSL LED which must be taken into account while calculating the junction temperature of the LED.

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About OSRAM Opto Semiconductors

OSRAM is part of the industry sector of Siemens and one of the two leading lighting manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany) and Penang (Malaysia). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

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