OSRAM
Opto Semiconductors

Application hints for high-current LEDs

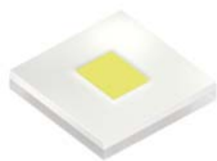
Application Note

Valid for:
OSLON Boost HX (KW CULPM1.TG)

Abstract

The OSLON Boost HX LED is optimized for applications which require high luminance. Therefore, the LED can be driven with high current densities, causing an extremely high thermal load. This requires the design of a ceramic based package to obtain low thermal resistance. The resulting size of the low R_{th} package requires special attention to the combination of the reliable solder joint and the type of MC-PCB (metal core PCB).

This application note covers the mentioned topics and provides suitable proposals.



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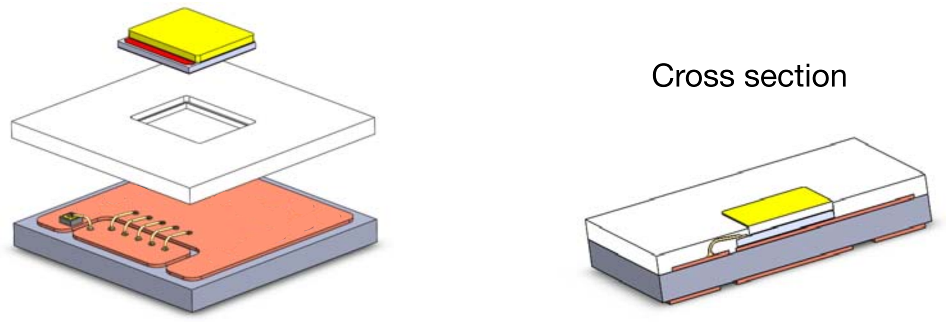
A. OSLON Boost LED

The OSLON Boost HX is primarily designed for high luminous intensity applications which require driving the LEDs with high currents. The OSLON Boost utilizes the high current capability of the latest chip generation in a special ceramic-based package for good thermal behavior. Figure 1 illustrates the design of the OSLON Boost as well as a cross section of the device.

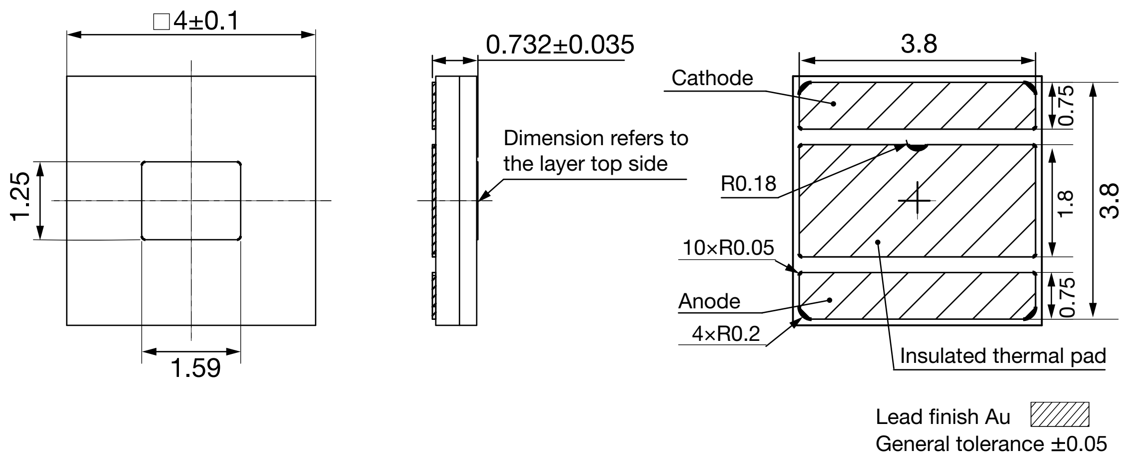
Figure 1: Design of the OSLON Boost HX



Mechanical dimensions

The OSLON Boost HX contains a 2 mm² chip. The dimensions of the chip and package as well as the solder pad design are shown in Figure 2.

Figure 2: Dimensions of the OSLON Boost HX 2 mm² chip size (KW CULPM1.TG)



For further information on the mechanical dimensions refer to the detailed drawings available in the data sheet.

B. Handling

ESD stability

The LED is equipped with an ESD protection diode, connected in parallel to the LED chip, which provides an ESD resistance of up to 8 kV according to ANSI/ESDA/JEDEC JS-001 (HBM, Class 3B).

Nevertheless, please be aware of ESD safety while handling LEDs. As a matter of principle, common ESD safety precautions must be observed during the handling, assembly and production of electronic devices (LEDs).

Precautions & storage

Generally, the LEDs are packaged in tape and on reels. For storage and dispatch, the reels are packed in vacuum-sealed dry bags together with desiccants.

It is generally recommended to leave unrequired reels in their packaging, and to store components during processing in ambient conditions of ≤ 10 % RH. Drying cabinets with dry nitrogen (N_2) or dry air are suitable for this type of storage.

Declaration of moisture sensitive Level 2 (MSL 2) according to JEDEC J-STD-020E.

Cleaning

From today's perspective any direct mechanical or chemical cleaning of the LED should be avoided. Isopropyl alcohol (IPA) can be used if cleaning is mandatory. Other substances, and especially ultrasonic cleaning, are generally not recommended.

For dusty LEDs, simple cleaning by means of purified compressed air (e.g. central supply or spray can) is recommended.

In any case, all materials and methods should be tested beforehand, particularly as to whether or not damage can be associated with the component.

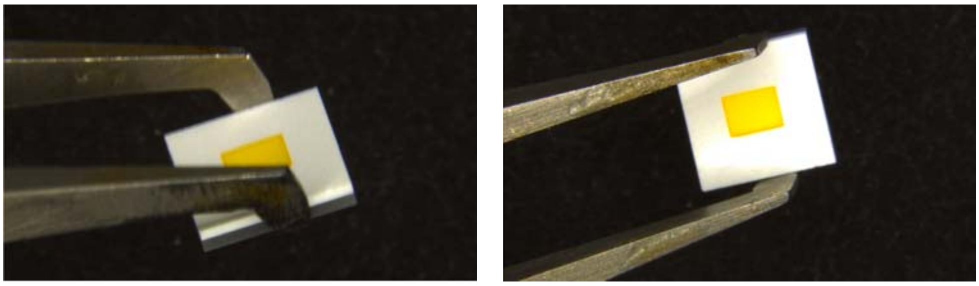
Manual handling

Following general guidelines for the handling of LEDs, additional care should be taken to minimize mechanical stress on the silicone encapsulation. In general, all types of sharp objects (e.g. forceps, fingernails, etc.) should be avoided to prevent damage to the encapsulation or wire bods, which could lead to the spontaneous failure of the LED.

For manual assembly and placement – in the production of prototypes, for example – the diligent use of tweezers is recommended. Therefore, the LED must be picked and handled only at the ceramic substrate (Figure 3).

Please be aware of ESD safety while handling the LED.

Figure 3: Manual handling

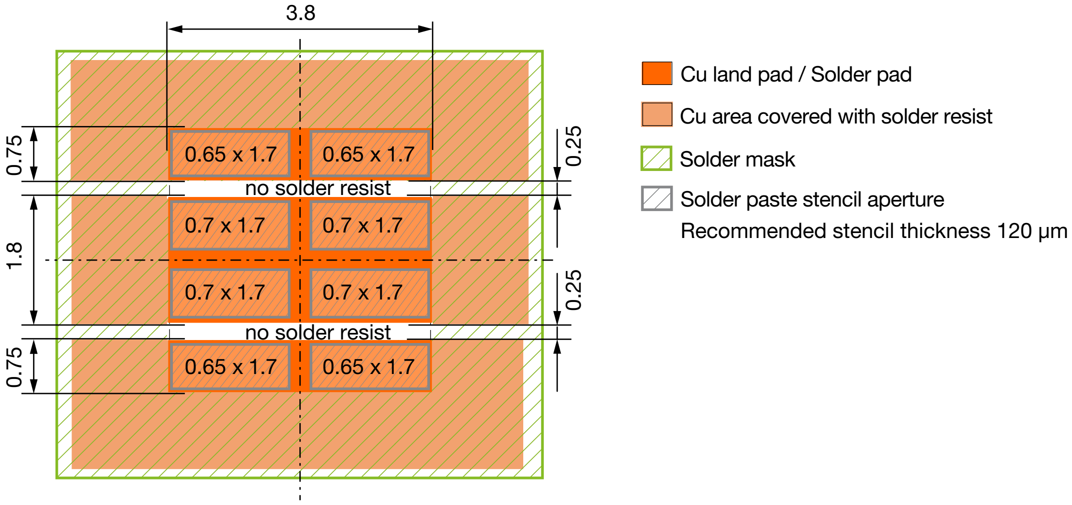


C. Processing

Solder pad design

The package is designed for reflow soldering. Figure 4 shows the solder pad proposal which can be used.

Figure 4: Proposal of a half SMD (solder mask defined) design

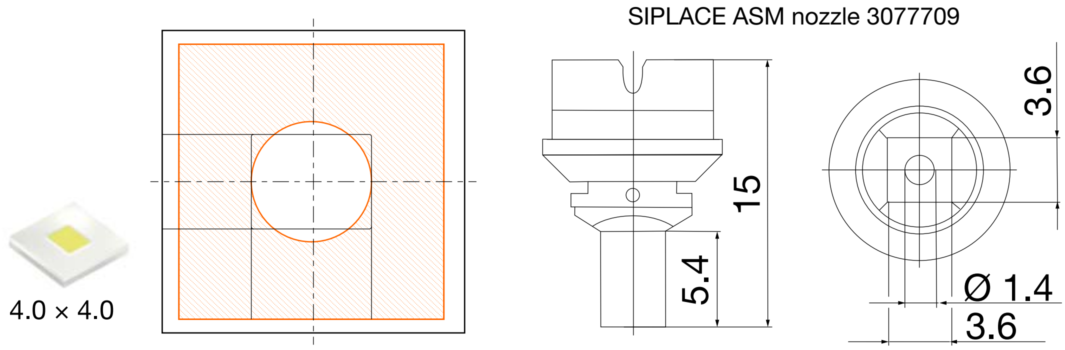


Pick-and-place nozzle design

When processing by means of automated placement machines, care should be taken to use an appropriate pick-and-place tool and to ensure that the process parameters are in conformance with the package's characteristics.

Figure 5 shows the recommended design of the placement tool for the damage-free processing.. In addition, an example for a suitable pick-and-place nozzle is given in the form of the SIPLACE tool number 3077709. Please ask your pick-and-place machine vendor for recommendations on the respective machine.

Figure 5: Recommended pick-and-place tool and recommended pick-up area



Reflow soldering

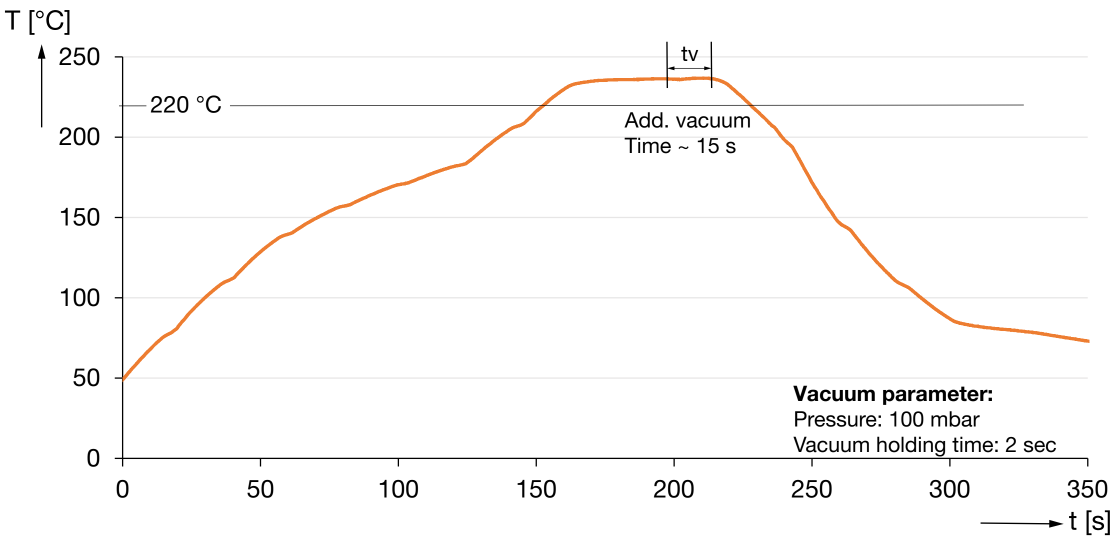
For an optimized heat transfer from the integrated thermal pad to the PCB and high board level reliability it is recommended to control the solder joint quality with an x-ray image.

The target is a reduction of the voids and bubbles in all solder joints. A total elimination of voids, particularly for the large thermal pad, is difficult. However, in in-house tests OSRAM Opto Semiconductors was able to achieve an acceptable void level by using a convection N_2 reflow oven including a vacuum chamber in the last reflow zone, in this case a Rehm VisionXP$^+$ with vacuum oven (see Figure 6).

Figure 6: Rehm VisionXP$^+$ with vacuum oven

The solder profile illustrated below is a more specific profile adapted to the size of the high-current LED and differs from the standard solder profile shown in the OSRAM Opto Semiconductors data sheets of various LEDs.

Figure 7: Recommended solder profile for the high-current LED



For superior solder joint connectivity results we recommend soldering under a standard nitrogen atmosphere. The package is not suitable for ultrasonic cleaning.

As with all LEDs from OSRAM Opto Semiconductors, the LED also fulfills the applicable RoHS guidelines (EU + China) and contains no lead or other defined hazardous substances.

The relevant information can also be found in the LED data sheet.

For a more precise mounting of the LED device an advanced solder process — with detection of the light emitting area and gluing before soldering — can be used.

D. PCB recommendations

For the OSLON Boost LED the selection of the right PCB technology is essential for the performance and the lifetime of the system. Dependent on the electrical power the LED is driven at, the following overview provides a first rough orientation on the possible PCB selection. The right choice is a combination of thermal performance and mechanical cycle stability (second board reliability) which also depends on the solder paste selection and the final PCB material composition. Therefore, the cycle tests of the assembled system at design validation and product validation must prove their fulfillment of the customers requirements. The following information is a comparison of thermal simulations with various PCB types to allow a rough classification of the performance required.

It gives no indication as to whether the material combination is appropriate to pass the cycle stability requirement. The following PCBs are compared in thermal simulations:

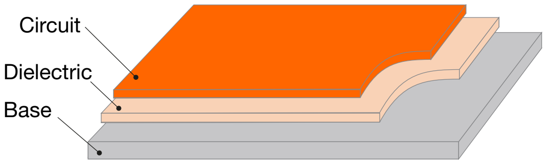
1. IMS — Insulated Metal Substrate PCB based on copper
   - Standard IMS substrate PCB
   - Enhanced IMS substrate PCB
2. General copper-based metal core (MC) PCB with micro vias (µVia)
   - FR4 laminated on copper with µVia PCB
3. FR4 PCBs with AlN inlay
4. Aluminum nitride (AlN) thick film ceramic PCB

1. IMS — Insulated Metal Substrate PCB based on copper

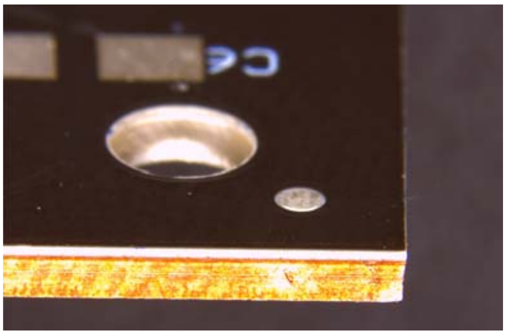
IMS are metal base plates with a thin dielectric and copper layer. Mostly, they are single layer PCBs. The thermal conductivity of the dielectric ranges from 0.2 - 5 $Wm^{-1}K^{-1}$. The structure of an IMS is schematically shown in Figure 8.

Figure 8: Schematic view and example of an IMS PCB

Schematic view of an IMS PCB



Example of an IMS PCB



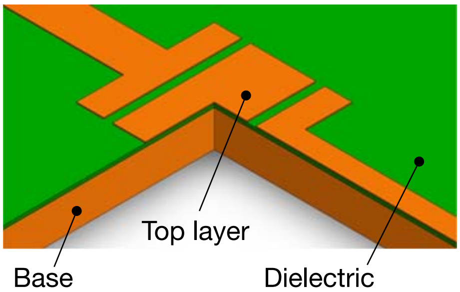
Copper layer/circuit: 18 µm, 35 µm - 400 µm
Dielectric: 17 µm, 38 µm, typ. 70 µm - 100 µm
Base plate: copper 0.5 mm - 3 mm

For the thermal simulations, a standard and an enhanced IMS PCB was selected in each case. The boundary conditions as well as the results of the thermal simulation are shown below.

1A. Standard IMS Substrate PCB

Figure 9: Thermal simulation of the heat spreading of the OSLON Boost HX

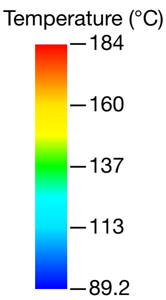
PCB technology:



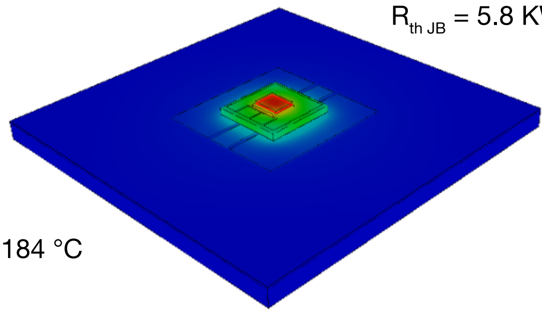
Boundary conditions:

- PCB on heat sink: $T_{Heatsink}$ = 85 °C
- P_{Heat} = 17 W @ $T_{Junction}$ = 120 °C (I_F = 6 A; typ. V_F = 3.4 V; 1000 lm)
- Heat conduction
- Steady state
- Standard IMS: 35 µm copper layer; 75 µm dielectric (1.3 $Wm^{-1}K^{-1}$); 1 mm copper base

Temperature scale:



Analysis results OSLON Boost HX:



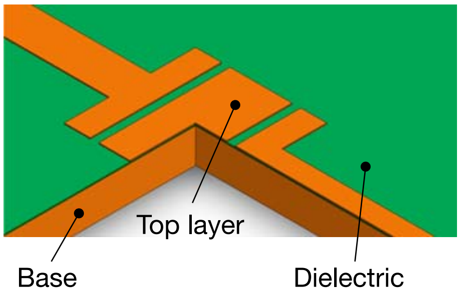
$R_{th\ JB}$ = 5.8 KW^{-1}

max. $T_{Junction}$ = 184 °C
@ T_{CP} = 85 °C

1B. Enhanced IMS Substrate PCB

Figure 10: Thermal simulation of the heat spreading of the OSLON Boost HX

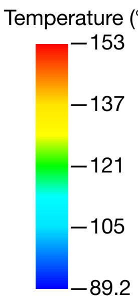
PCB technology:



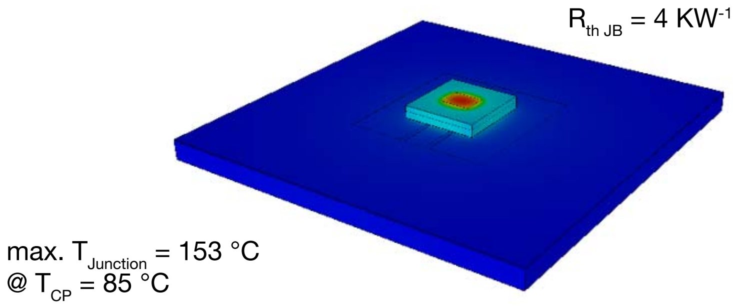
Boundary conditions:

- PCB on heat sink: $T_{Heatsink}$ = 85 °C
- P_{Heat} = 17 W @ $T_{Junction}$ = 120 °C (I_F = 6 A; typ. V_F = 3.4 V; 1000 lm)
- Heat conduction
- Steady state
- Enhanced IMS substrate: 35 µm copper layer; 38 µm dielectric (3 $Wm^{-1}K^{-1}$); 1 mm copper base

Temperature scale:



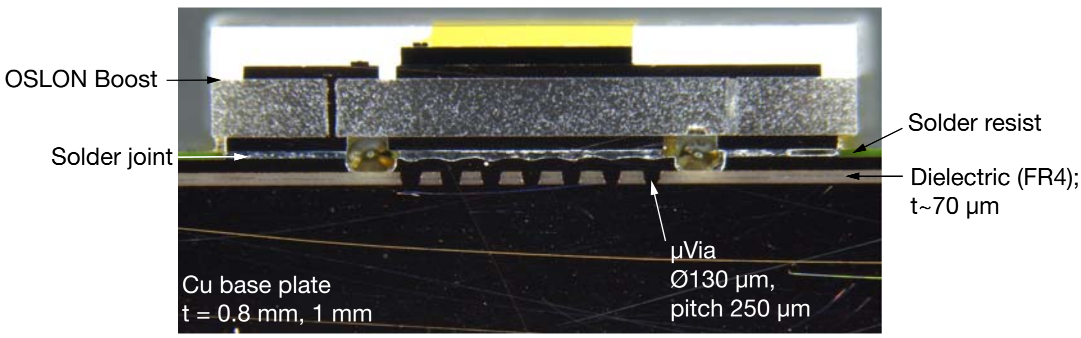
Analysis results OSLON Boost HX:



2. General copper-based metal core PCBs with micro vias (µVias)

The MC PCBs with micro vias are suitable for components with an electrically isolated thermal pad. This technology has been adapted from high-density interconnection (HDI). The micro vias are filled with copper. The typical micro via diameter is 130 µm, while the possible array pitch is 250 µm. Figure 11 shows examples of the MC PCBs with micro vias.

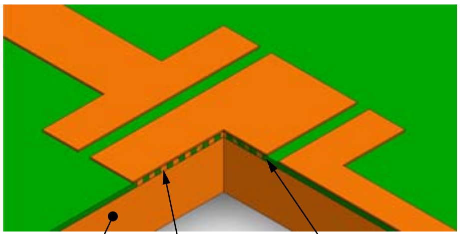
Figure 11: Example of a copper based MC PCB with µVias



2A. FR4 laminated on copper with µVia PCB

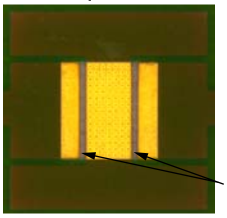
Figure 12: Thermal simulation of the heat spreading of the OSLON Boost HX

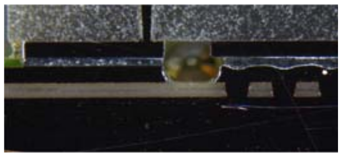
PCB technology:



Boundary conditions:

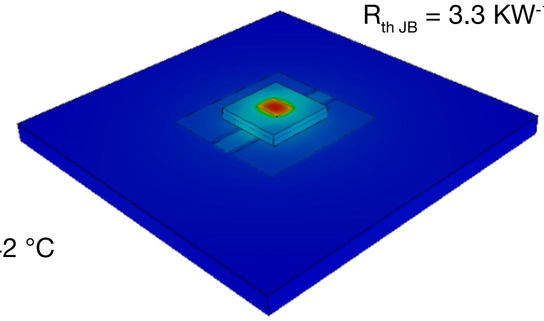
- PCB on heat sink: $T_{Heatsink}$ = 85 °C
- P_{Heat} = 17 W @ $T_{Junction}$ = 120 °C (I_F = 6 A; typ. V_F = 3.4 V; 1000 lm)
- Heat conduction
- Steady state
- FR4 laminated on copper with µVia PCB





Temperature scale:

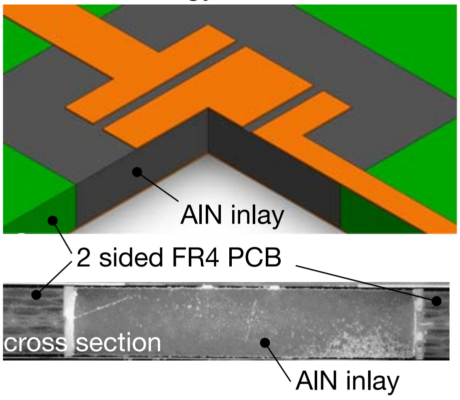
Analysis results OSLON Boost HX:



3. FR4 PCB with AlN inlay

Figure 13: Thermal simulation of the heat spreading of the OSLON Boost HX

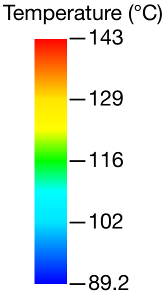
PCB technology:



Boundary conditions:

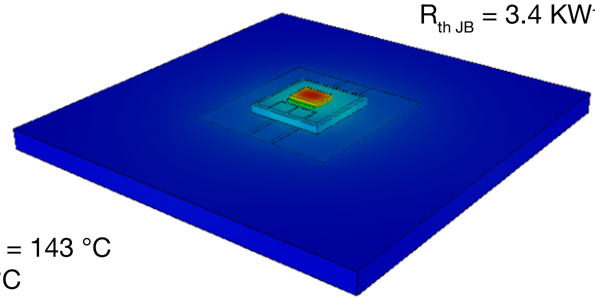
- PCB on heat sink: $T_{Heatsink}$ = 85 °C
- P_{Heat} = 17 W @ $T_{Junction}$ = 120 °C (I_F = 6 A; typ. V_F = 3.4 V; 1000 lm)
- Heat conduction
- Steady state
- 2 sided FR4 PCB: 35 µm copper layer; 1 mm FR4; 35 µm copper layer; AlN inlay 7 mm × 7 mm × 7 mm

Temperature scale:



Analysis results OSLON Boost HX:

$R_{th\ JB}$ = 3.4 KW^{-1}

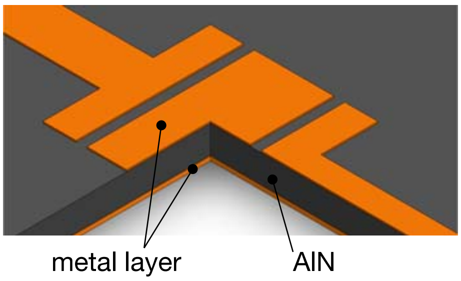


max. $T_{Junction}$ = 143 °C
@ T_{CP} = 85 °C

4. Aluminum Nitride (AlN) thick-film ceramic PCB

Figure 14: Thermal simulation of the heat spreading of the OSLON Boost HX

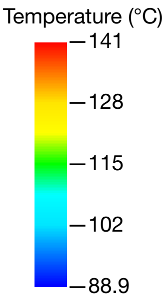
PCB technology:



Boundary conditions:

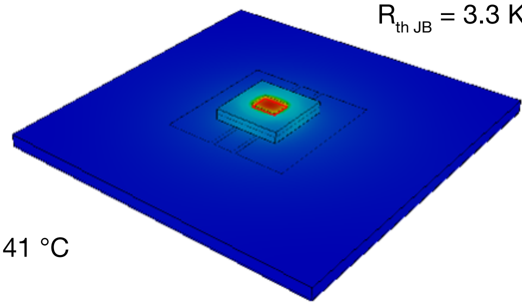
- PCB on heat sink: $T_{Heatsink}$ = 85 °C
- P_{Heat} = 17 W @ $T_{Junction}$ = 120 °C (I_F = 6 A; typ. V_F = 3.4 V; 1000 lm)
- Heat conduction
- Steady state
- AlN thick film ceramic PCB: 40 µm metal layer; 635 µm AlN ceramic; 100 µm metal layer

Temperature scale:



Analysis results OSLON Boost HX:

$R_{th\ JB}$ = 3.3 KW^{-1}



max. $T_{Junction}$ = 141 °C
@ T_{CP} = 85 °C

Overview of the results

Table 1 gives an overview of the results of the thermal simulations previously shown.

Table 1: Overview of the results of the thermal simulation

Entry	PCB technology	T_J /°C[1]	$\Delta T_{J\ HS}$ /°C	$R_{th\ JB}$ /KW^{-1}
1A	Standard IMS substrate[2]	184	99	5.8
1B	Enhanced IMS substrate	153	68	4.0
2	FR4 laminated on Cu with μVia array	142	57	3.3
3	FR4 PCB with AlN inlay	143	58	3.4
4	AlN thick-film ceramic	141	56	3.3

[1]at T_{HS} = 85 °C

[2]not recommended

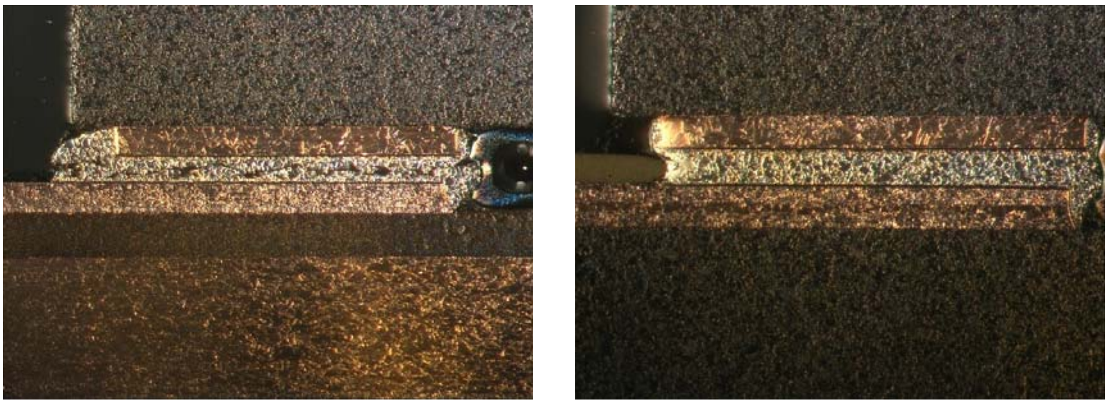
Second board reliability temperature cycle (TC) stability

Second board reliability was evaluated on various PCB materials (Cu based IMS PCB with μVias and ceramic inlay PCBs) using accelerated temperature cycle tests. The results of the tests show that high CTE board materials will cause higher thermo-mechanical stress on the solder joint and will lead to faster solder fatigue. Figure 15 shows the corresponding metallographic cuts of the PCBs after the respective temperature cycles.

Figure 15: Picture of metallographic cuts after the TC stability test

Cu μVia
@1400 C; TC -40°C / 150°C

ceramic inlay
@1800 C; TC -40°C / 150°C



Here, the solder joint of the Cu IMS with μVia PCB show a crack after the cycle test, while the solder joint of the ceramic inlay PCBs remained intact. Thus, from the cycle stability point of view a PCB with ceramic inlay is the best performing material, whereas an aluminum-based IMS is not suitable. However, depending on the customer application, a Cu IMS with μVia PCBs might be suitable as well.

The various test conditions are shown in Table 2.

Table 2: Second board evaluation

Entry	PCB	Test condition /°C	Duration
1	Cu µVia	-40 /150	1400 Cycles
2	Cu µVia	-40 /125	1400 Cycles
3	ceramic inlay	-40 /150	1800 Cycles
4	ceramic inlay	-40 /125	1800 Cycles

Conclusion

The thermal load dissipation and the temperature cycle mechanical stability are two important parameters for the use of the high-current OSLON Boost LED. Both of them are influenced by the solder joint quality and the PCB type and material selection. Thus, only a conscientious design validation and product validation of the respective system can assure the right selection of the material to be used.

E. Appendix

For the thermal simulations, the PCBs from the suppliers mentioned below were used as examples:

Table 3: PCB Examples used for thermal simulations

Entry	PCB technology	PCB supplier and product
1A	Standard IMS substrate	Bergquist MP
1B	Enhanced IMS substrate	Bergquist HPL
2	FR4 laminated on Cu with µVia array	Schweizer, AT&S
3	FR4 PCB with AlN inlay	RayBen MHE901
4	AlN thick film ceramic	

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