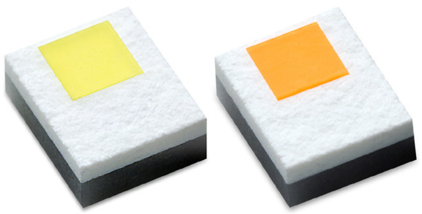
LUMILEDS

AUTOMOTIVE

LUXEON FX2

Assembly and Handling Information



Introduction

This application brief addresses the recommended assembly and handling procedures for LUXEON FX2. The LUXEON FX2 is designed to deliver high luminous flux and efficacy in automotive exterior lighting applications. As a matter of principle, LEDs require special assembly and handling precautions.

Proper assembly, handling and thermal management, as outlined in this application brief, ensures high optical output, long term lumen maintenance and high reliability of the LUXEON FX2 in automotive applications.

Scope

The assembly and handling guidelines in this application brief apply to the products:

PRODUCTS
LUXEON FX2 Cool White
LUXEON FX2-L Cool White
LUXEON FX2 Plus Cool White
LUXEON FX2-L Plus Cool White
LUXEON FX2 PC Amber
LUXEON FX2-L PC Amber
LUXEON FX2 Plus PC Amber
LUXEON FX2-L Plus PC Amber

Any assembly or handling requirements that are specific to a subset of the LUXEON FX2 products is clearly marked.

In the remainder of this document, the term LUXEON FX2 refers to any product in the LUXEON FX2 product family.

Where further differentiation between the two package size are necessary the term LUXEON FX2 Plus refers to all family members carrying a Plus in their description.

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1. Component

1.1 Reference Document

The LUXEON FX2 datasheets are available upon request. Please contact your sales representative.

1.2 Description

The LUXEON FX2-LED consists of a single chip, combined with a phosphor converter. This LED Chip is placed on an AIN carrier substrate and the electrical and thermal pads are formed on the bottom side of this AlN carrier. The outside of the package is coated with white silicone to shield the chip from environment and to prevent light leakage to the sides (top emitter). The LUXEON FX2-LED includes a separate transient voltage suppressor (TVS) chip on top of the carrier substrate, that is covered by side coat. The TVS shall protect the emitter against electrostatic discharges (ESD). For the subset LUXEON FX2 Plus a dedicated thermal pad is located beneath the LED chip as can be seen in Figure 2.

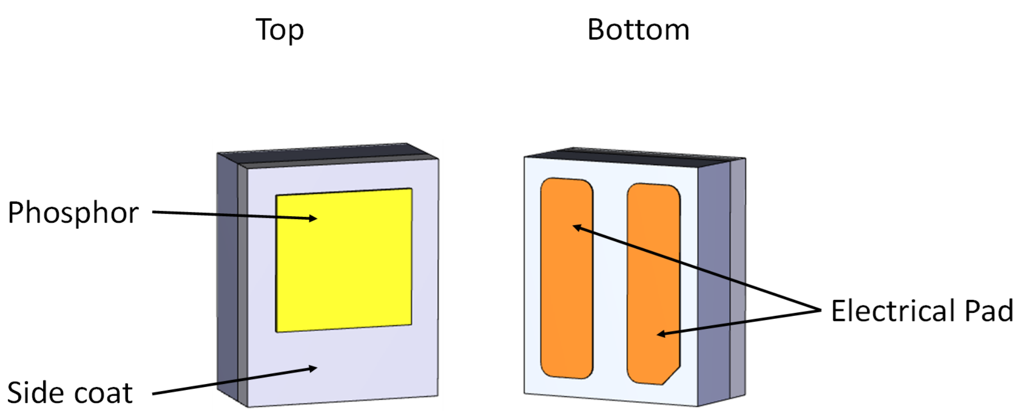


Figure 1. Top view (left) and bottom view (right) of the LUXEON FX2

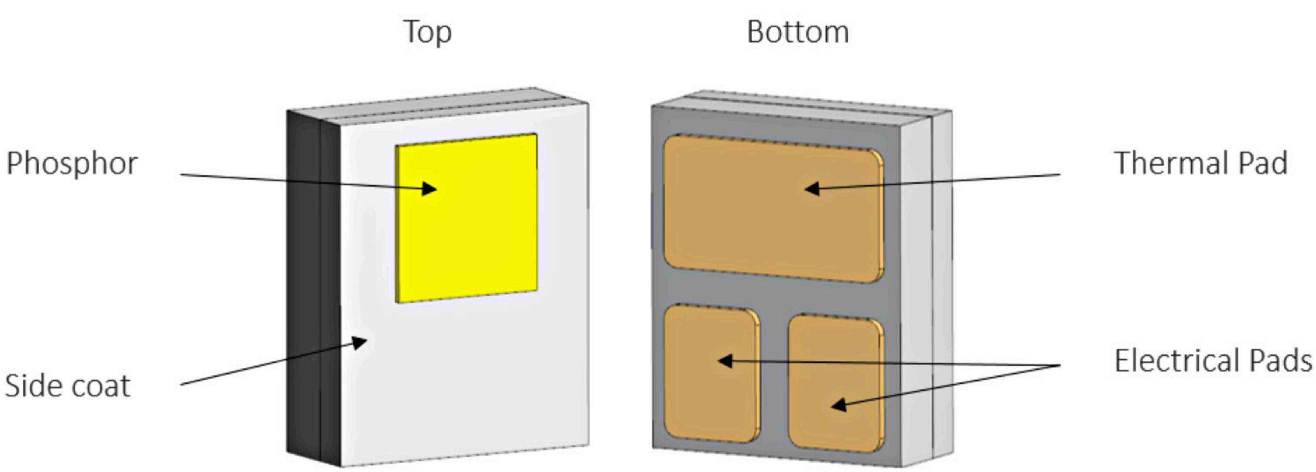


Figure 2. Top view (left) and bottom view (right) of the LUXEON FX2 Plus

Table 1. Design features by LUXEON FX2 part number

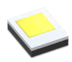
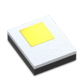
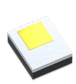
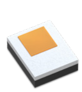
PRODUCT PHOTO	PRODUCT DESCRIPTION	PART NUMBER	NOMINAL DRIVE CURRENT (mA)	PACKAGE SIZE (mm)	LIGHT EMITTING AREA (mm)	NUMBER OF PADS	ESD PROTECTION
	FX2 CW	A1F2-5850S2Axxxxx	1000	1.50 x 1.85 x 0.798	1.06 x 1.06	2	Internal TVS-diode
		A1F2-5850S2Cxxxxx	1000	1.50 x 1.85 x 0.813			
	FX2-L CW	A1F2-5850F2Axxxxx	1000	1.50 x 1.85 x 0.798	1.15 x 1.15	2	Internal TVS-diode
		A1F2-5850F2Cxxxxx	1000	1.50 x 1.85 x 0.813			
	FX2 PCA	A1F2-0591S2Axxxxx	1000	1.50 x 1.85 x 0.838	1.06 x 1.06	2	Internal TVS-diode
	FX2-L PCA	A1F2-0591F2Axxxxx	1000	1.50 x 1.85 x 0.838	1.15 x 1.15	2	Internal TVS-diode
		A1F2-0591F2Cxxxxx	1000	1.50 x 1.85 x 0.890			

Table 2. Design features by LUXEON FX2 Plus part number

PRODUCT PHOTO	PRODUCT DESCRIPTION	PART NUMBER	NOMINAL DRIVE CURRENT (mA)	PACKAGE SIZE (mm)	LIGHT EMITTING AREA (mm)	NUMBER OF PADS	ESD PROTECTION
	FX2 Plus CW	A1F2-5850S3Axxxxxx	1000	1.92 x 2.34 x 0.798	1.06 x 1.06	3	Internal TVS-diode
		A1F2-5850S3Cxxxxx	1000	1.92 x 2.34 x 0.813			
	FX2-L Plus CW	A1F2-5850F3Axxxxx	1000	1.92 x 2.34 x 0.798	1.15 x 1.15	3	Internal TVS-diode
		A1F2-5850F3Bxxxxxx	1000	1.92 x 2.34 x 0.807			
		A1F2-5850F3Cxxxxx	1000	1.92 x 2.34 x 0.813			
	FX2 Plus PCA	A1F2-0591S3Axxxxx	1000	1.92 x 2.34 x 0.838	1.06 x 1.06	3	Internal TVS-diode
	FX2-L Plus PCA	A1F2-0591F3Axxxxx	1000	1.92 x 2.34 x 0.838	1.15 x 1.15	3	Internal TVS-diode
		A1F2-0591F3Cxxxxx	1000	1.92 x 2,34 x 0.890			

1.3 Form Factor

The dimensional design for LUXEON FX2 is outlined below in Figure 3 and for LUXEON FX2 Plus in Figure 4. The different dimensions, related to the type, are listed in Table 1 and Table 2. See the latest LUXEON FX2 datasheet for detailed dimensions and applicable tolerances.

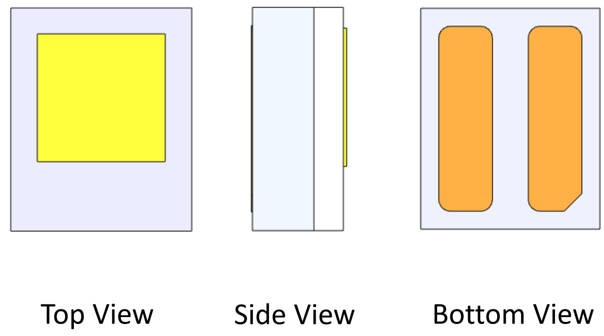


Figure 3. Outline dimensions for LUXEON FX2

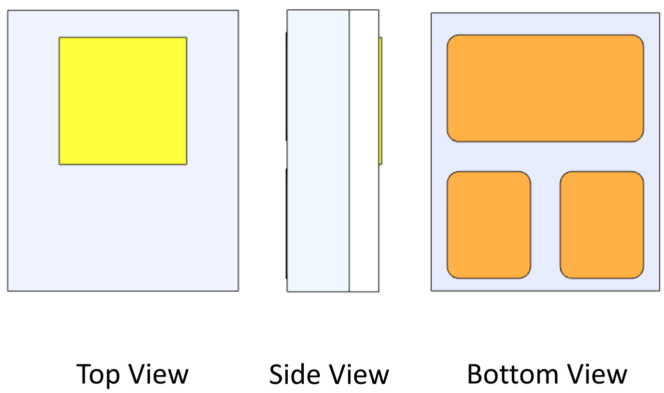


Figure 4. Outline dimensions for LUXEON FX2 Plus

1.4 Optical Center

The LUXEON FX2 has no lens (primary optics). The optical center is at the center of the ceramic phosphor converter as indicated by the red dot, and the center of LED package is indicated by the green dot, both shown in Figure 5. The distance of optical center to package center is nominal 0.46mm. See datasheet for latest information on tolerances. Optical rayset data of each LUXEON FX2 part is available upon request.

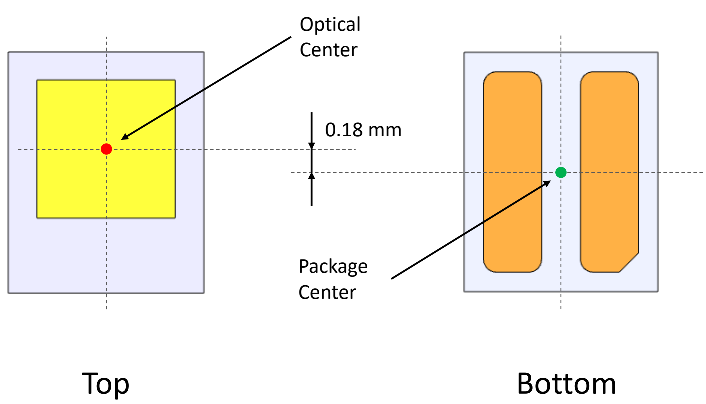


Figure 5. Nominal optical center and geometrical package center for LUXEON FX2

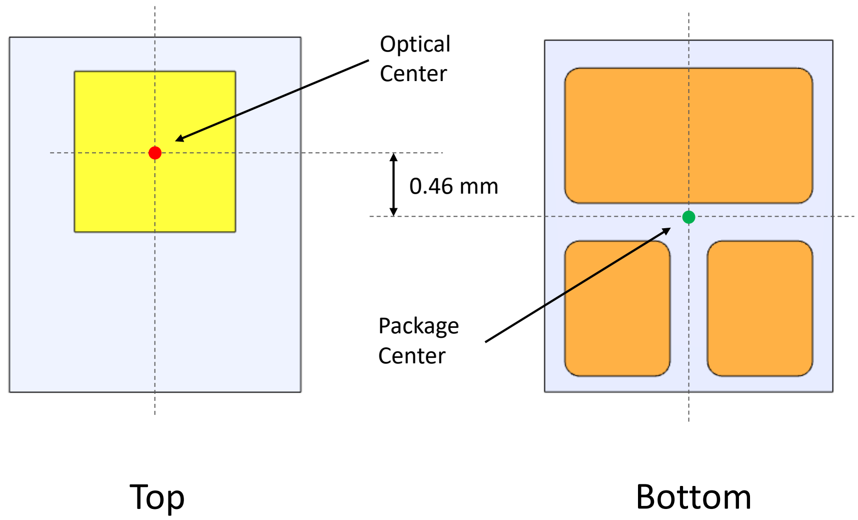


Figure 6. Nominal optical center and geometrical package center for LUXEON FX2 Plus

1.5 Mechanical Files

Mechanical drawings and CAD-files for the LUXEON FX2 are available upon request. For details, please contact your sales representative.

2. Handling Precautions

2.1 Electrostatic Discharge (ESD) Protection

As shown in Table 1 and 2, the LUXEON FX2 is ESD protected by an additional TVS device. This transient voltage suppressor (TVS) diode provides a current path for transient voltages (see Figure 7).

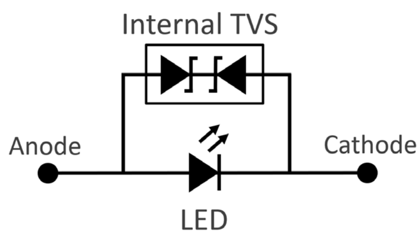


Figure 7. Electrical schematic of an LED with internal TVS

Common causes of ESD inlude the direct transfer of charges from the human body or from a charged conductive object to the LED component. In order to test the susceptibility of LEDs to these common causes of ESDs, two different models are typically used:

- Human Body Model (HBM)
- Charged Device Modell (CDM)

The LUXEON FX2 has been independently verified to successfully pass ESD tests under HBM and CDM conditions. For the respective test voltages of these tests please refer to the latest LED datasheets. Additional external ESD protection for the LED may be needed if the LED is used in non ESD-protected environments or exposed to higher ESD voltages and discharge energies, e.g. as described in ISO 10605 or IEC 61000-4-2 (severity level IV). For details please contact your sales representative.

Machine (MM) is redundant to HBM at the device level since it produces the same failure mechanisms and the two models generally track each other in robustness and in failure modes produced and is therefore obsolet.

2.2 Component Handling

Minimize all mechanical forces exerted onto the LED package. It should not be handled with tweezers that can lead to damage of the package, especially not with metallic tweezers. Any force above 2.0 N may damage the LED and change optical performance. A vacuum pen can be used instead of tweezers (see Figure 8)

The suction tip should be made of a soft material such as rubber to minimize the mechanical force exerted onto the top surface of the LED. Avoid contaminating the top side surface of the LED. Do not stick any tape on top of the light emitting surface, such as Kapton™- or UV-tape. A contamination with glue or its invisible constituent parts may change the LED performance.

Electrical testing before assembly should be avoided. Probe tips may scratch or dent the pad surface, which may lead to solder issues, and damage the LED. Avoid any contact with the LED other than what is required for placement.

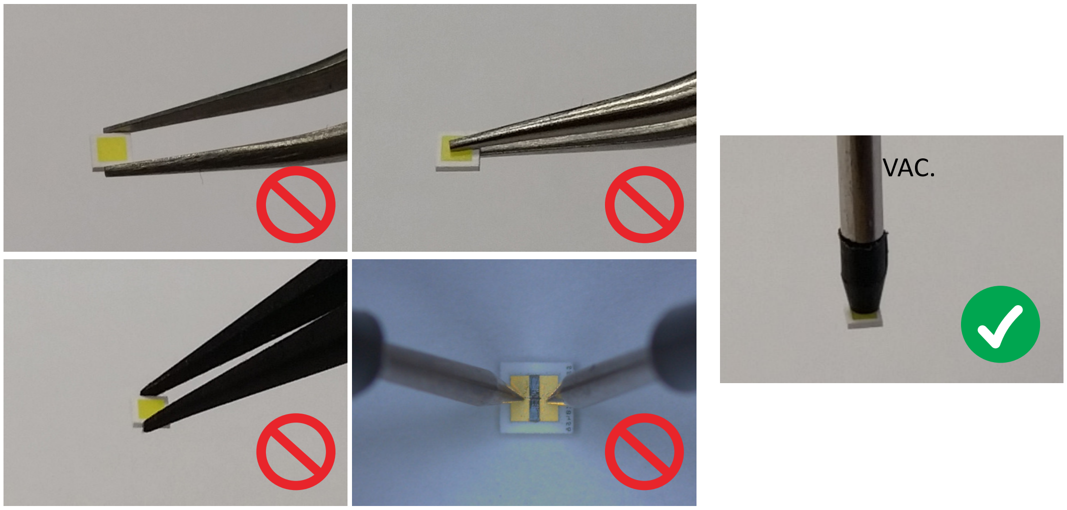


Figure 8. LED handling

Do not touch the top surface with fingers or apply any pressure to it when handling finished boards equipped with LEDs. Do not stack finished boards because the LEDs can be damaged by the other board outlines. In addition, do not put finished boards with LEDs top side down on any surface. The surface of a workstation may be rough or contaminated and may damage the LEDs. These warnings are shown in Figure 9.

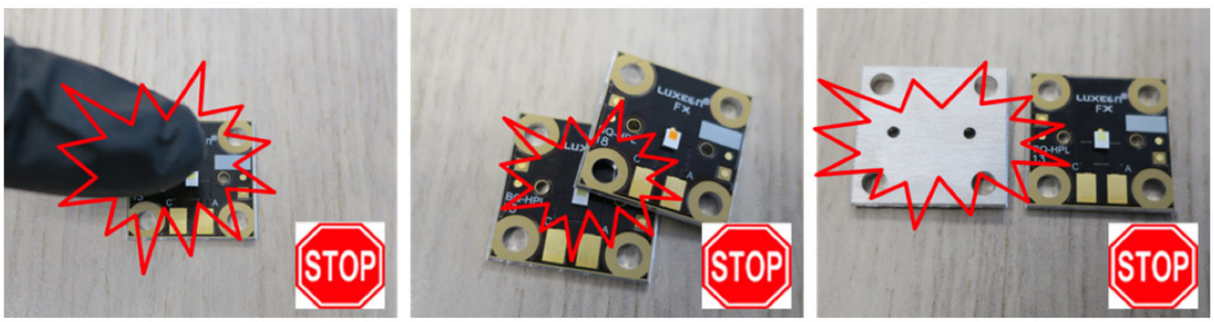


Figure 9. Board handling

2.3 Cleaning

The surface of the LED should not be exposed to dust and debris. Excessive dust and debris on the LED surface may cause a decrease in light output and optical behavior. It is best to keep LEDs in their original shipping reel until actual use.

In the event that the surface requires cleaning, a compressed gas duster or an air gun with 1.4 bar (at the nozzle tip) and a distance of 15 cm will be sufficient to remove the dust and debris. Make sure that the parts are secured first, taking above handling precautions into account.

One can also rinse with isopropyl alcohol (IPA). Do not use solvents listed in Table 12, as they may adversely react with the LED assembly. Extra care should be taken not to damage the housing around the LED chips. Lumileds does not recommend ultrasonic supported cleaning for LEDs.

3. Printed Circuit Board

3.1 PCB Requirements

The LED can be mounted on multi-layer FR4 printed circuit boards (PCB) or insulated metal substrates (IMS). To ensure optimal operation of the LED, the thermal path between the LED package and the heat sink should be optimized according to the application requirements. Please ensure that the PCB assembly complies to the applicable IPC standards listed below.

General PCB Standards:

- IPC A-600H: Acceptability of Printed Boards
- IPC A-610F: Acceptability of Electronic Assemblies
- IPC 2221A: General Standard on Printed Board Design
- IPC 7093: Design and Assembly Process Implementation for Bottom Termination Components

Filled and capped via boards:

- IPC 4761: Design Guide for Protection of Printed Board Via Structures
- IPC 2315: Design Guide for High Density Interconnects and Micro Vias
- IPC 2226: Design Standard for High Density Interconnect Printed Boards

3.2 Footprint and Land Pattern

Lumileds recommends for the LUXEON FX2 using of a metal defined land pattern, as shown in Figure 10. Consider that metal defined land pattern, leaves less area for the heat spreading of the thermal power, generated by the LED. Also higher tolerances for LED tilting and position tolerances can be encountered. Positive aspect is, that the requirements to the printed circuit board tolerance for solder mask alignment to metal structure are lower than for solder mask defined land pattern.

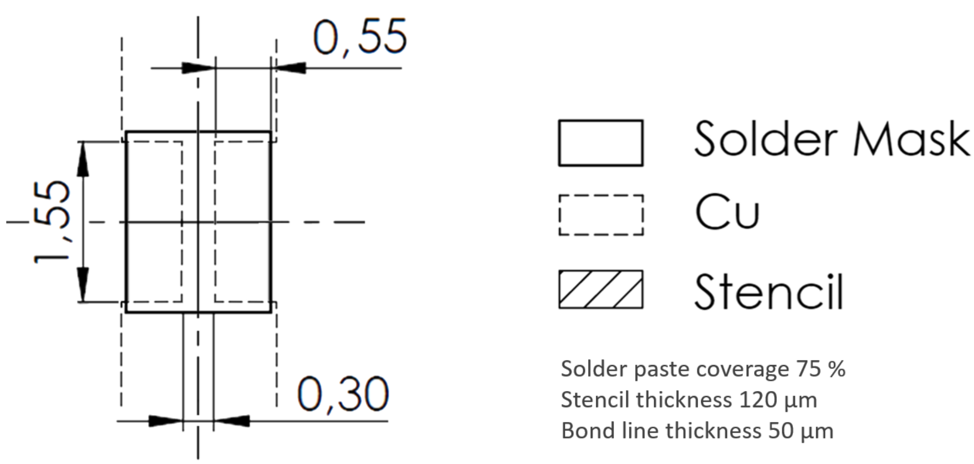


Figure 10. Metal defined land pattern for LUXEON FX2

For the LUXEON FX2 Plus, Lumileds recommends a solder mask defined land pattern, as shown in Figure 11. The copper area can be extended as far as possible for better heat spreading, which results in lower thermal resistance. However, a solder mask defined pad requires good mask quality and tight registration tolerances during PCB manufacturing (see Chapter 3.7 “PCB Quality and Supplier” for more details).

For the solder mask defined land pattern, the self-alignment of the component during reflow soldering can be controlled well by solder mask geometry in X- and Y-direction.

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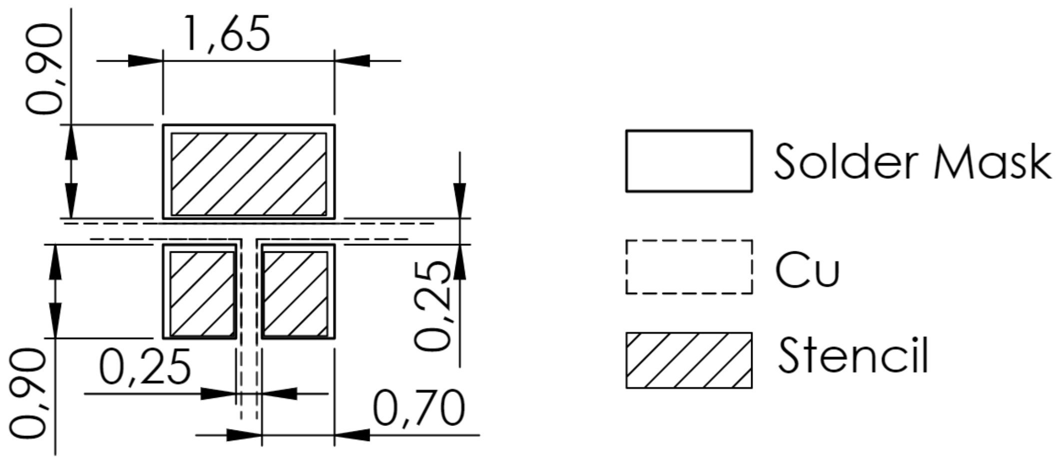


Figure 11. Metal defined land pattern for LUXEON FX2 Plus

3.3 Surface Finishing

Lumileds recommends using ENIG (Electroless Nickel Immersion Gold) plating according to IPC-4552. Other surface finishes are possible but have not been tested by Lumileds. Surface finish Hot-Air-Solder-Leveling (HASL) may have inhomogenious pad height and is not recommended. Unsymmetrical solder thickness may have an influence on LED height and soldering tolerances. The actual quality of HASL finish shall be checked in each single case.

3.4 Solder Mask

A flat solder mask thickness on top of metal layer is desired. Solder mask thickness variation and offset tolerances have impact on solder quality and post-solder position accuracy. Mask and PCB vendors have to be evaluated for proper quality. Detailed specifications and information regarding solder mask requirements are contained in IPC-6012 and IPC-SM-840. (see chapter "PCB Quality and Supplier", Figure 12 for more details).

3.5 Silk Screen or Ink Printing

Silk screen markings within and around the LED outline should be avoided because the height of the ink may interfere with the solder stencil printing process.

3.6 PCB Quality and Supplier

Select only PCB suppliers that are capable of delivering the required level of quality. The PCBs must comply with IPC standard IPC-A-600J, 2016 ("Acceptability of Printed Boards") or superseding3l document.

A maximum mask registration tolerance of 50 µm between the copper trace pattern and solder mask is desirable to achieve optimum solder joint contact area using the recommended solder mask defined footprint as shown in Figure 10. If the offset between the solder mask and the copper land pattern is large, one side of electrode pads will have less solder joint contact area. This may affect package centering, tilting, and thermal performance and may increase risk of solder bridging (short circuit) and solder balling if the stencil is not properly aligned to the solder mask during printing.

Figure 12 shows an example of the solder pad size for different registration offset levels between the copper trace pattern and the solder mask for LUXEON FX2 using the recommended footprint in Figure 12. Large misalignment between solder mask opening and copper trace will cause one of the two electrode copper land patterns to be smaller than the other. Depending on the PCB manufacturer capability, PCB cost consideration and customer position tolerance needs, it may be necessary to extend the area of the solder mask opening.

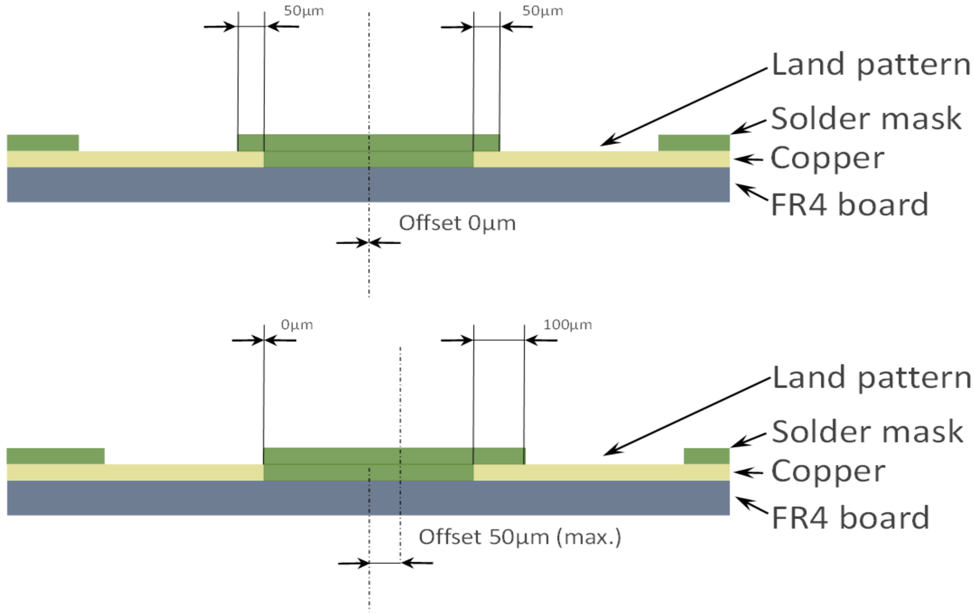


Figure 12. Solder mask registration offset to copper trace

4. Thermal Measurement Guidelines

4.1 Thermal Resistance

The thermal resistance between the junction of the LED and the bottom side of the PCB depends on the following key design parameters of a PCB:

- PCB dielectic materials
- Cu plating thickness
- Solder pad pattern and solder thickness
- Distance to neighbogring heat source (LED spacing)

Lumileds conducted simulations to evaluate the thermal performance of LUXEON FX2 on different PCB design concepts. Details of the simulation model are given in Figure 13. The model geometry comprises the LED on a board (metal-core printed circuit board or FR4 board) that is mounted on a plate Al heatsink. A thermal interface material (TIM) is assumed between board and heatsink. The thermal resistances junction-to-board bottom $R_{th,j\text{-}b,el}$ (thermal resistance based on electrical input power) are calculated as $R_{th,j\text{-}b,el} = R_{th,j\text{-}b,real}/(1\text{–}WPE)$, where WPE denotes the wall plug efficiency. The WPE is not constant and depends on drive condition and flux binning class. The thermal resistance $R_{th,j\text{-}b,real}$ is based on thermal power and is obtained by $R_{th,j\text{-}b,real} = (T_j\text{-}T_b)/P_{th}$, where T_j is the average junction temperature, T_b the maximum temperature at the bottom side of the board obtained from the simulations, and P_{th} the thermal input power.

Simulation Details

Simulation Model

- LED on board and plate heat sink with TIM
- Simulation of heat conduction and radiation
- Bottom of heat sink is assumed to be ideally heat-sunk to ambient

Heat Sink and TIM Parameters

- Heat sink size: 50 mm x 50 mm x 5 mm
- Heat sink material: Al – 150 W/(mK)
- TIM thickness: 100 µm
- TIM th. cond.: 2 W/(mK)

Board Parameters

- Board area: 20 mm x 20 mm
- Board thickness: 1.0 mm (Cu-IMS) or 1.6 mm (Al-IMS, FR4)
- Cu layer thickness: 70 µm
- Solder mask: 20 µm
- IMS diel. thickness: 75 µm or 38 µm

Board Thermal Conductivities

- Cu: 390 W/(mK)
- IMS dielectric: 2.2 W/(mK) or 3 W/(mK)
- FR4 epoxy: 0.3 W/(mK)
- Vias plating: 390 W/(mK)
- Vias filling: 0.3 W/(mK)
- Solder mask: 0.2 W/(mK)

Solder Parameters

- Thickness (BLT): 90 µm
- Th. conductivity: 56 W/(mK)

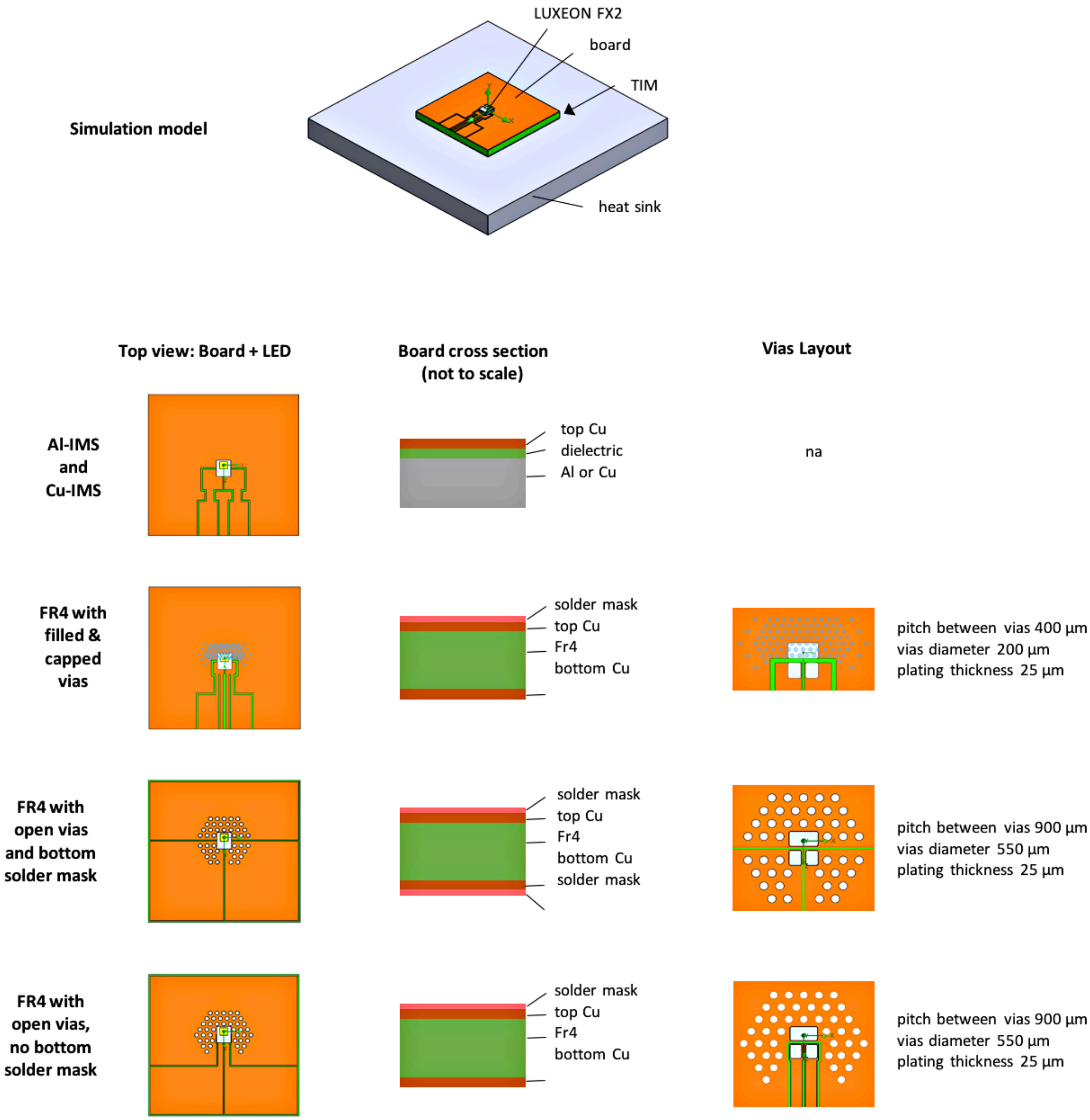


Figure 13. Model geometry and board parameters used for the simulation

Table 3a and 3b list the simulated LED-junction-to-board-bottom thermal resistances Rth,j-b,real (based on thermal power) and the thermal resistances Rth,j-b,el (based on electrical power) for LUXEON FX2 Plus and LUXEON FX2 on different board. The thermal resistances Rth,j-b,el have been calculated assuming a WPE for LUXEON FX2 CW and LUXEON Plus CW of 0.3, as well for LUXEON FX2 PCA and LUXEON FX2 Plus PCA of 0.25.

Table 3a. Simulated thermal resitances for LUXEON FX2 Plus

BOARD MATERIAL/DIELECTRIC	LUXEON FX2 PLUS CW		LUXEON FX2 PLUS PCA	
	$R_{th,j\text{-}b,real}$ (K/W)	$R_{th,j\text{-}b,el}$ (K/W)	$R_{th,j\text{-}b,real}$ (K/W)	$R_{th,j\text{-}b,el}$ (K/W)
1.0 mm Cu-IMS, 3 W/(mK) – 38 µm dielectric	7.6	5.3	7.6	5.7
1.0 mm Cu-IMS, 2.2 W/(mK) – 75 µm dielectric	9.0	6.3	9.0	6.7
1.6 mm Al-IMS, 3 W/(mK) – 38 µm dielectric	7.8	5.5	7.8	5.9
1.6 mm Al-IMS, 2.2 W/(mK) – 75 µm dielectric	9.2	6.5	9.2	6.9
1.6 mm FR4 with filled and capped vias in thermal pad region	12.0	8.4	12.0	9.0
1.6 mm FR4 with open vias around thermal pad, no bottom solder mask	14.6	10.2	14.6	10.9
1.6 mm FR4 with open vias around thermal and electrical pads, bottom solder mask	16.2	11.3	16.2	12.2

Table 3b. Simulated thermal resitances for LUXEON FX2

BOARD MATERIAL/DIELECTRIC	LUXEON FX2 CW		LUXEON FX2 PCA	
	$R_{th,j\text{-}b,real}$ (K/W)	$R_{th,j\text{-}b,el}$ (K/W)	$R_{th,j\text{-}b,real}$ (K/W)	$R_{th,j\text{-}b,el}$ (K/W)
Cu-IMS 1.0 mm 3 W/(mK) 38 µm dielectric	8.4	5.8	8.4	6.3
Cu-IMS 1.0 mm 2.2 W/(mK) 75 µm dielectric	9.8	6.8	9.8	7.3
Al-IMS 1.6 mm 3 W/(mK) 38 µm dielectric	8.6	6.0	8.6	6.5
Al-IMS 1.6 mm 2.2 W/(mK) 75 µm dielectric	10.0	7.0	10.0	7.5
FR4 F&C vias 1.6 mm	12.8	8.9	12.8	9.6
FR4 open vias 1.6 mm, no bottom SM	15.4	10.7	15.4	11.5
FR4 open vias 1.6 mm	17.0	11.8	17.0	12.8

4.2 Close-Proximity Thermal Performance

The For small distances between the individual LEDs, thermal crosstalk can occur, leading to enhanced junction temperatures. Lumileds recommends using thermally well performing boards with high-conductivity dielectric to optimize the thermal performance.

Lumileds conducted thermal simulations of a 2x2 and a 2x3 LED arrangement of varying distance between the LEDs as schematically shown in Figure 14. The thermal resistances $R_{th,j\text{-}b,real}$ of an Al-IMS board and an FR4 board with filled and capped vias in the thermal pad region were analyzed. The board size was 60 mm x 60 mm. The vias region in the FR4 epoxy was modelled as a region of anisotropic thermal conductivity with an in-plane conductivity of $k_{||}$ = 0.3 W/(mK) and an out-of-plane conductivity of $k_{\perp}$ = 38 W/(mK), corresponding to a fractional Cu area of ~10%. This value is in line with the vias pattern given in Figure 13. Other board parameters are chosen as described in section 4.1 The same power was assigned to all LEDs in the array. The simulated thermal resistances from junction to board bottom $R_{th,j\text{-}b,real}$ are given in the graphs in Figure 14. They have been calculated using the simulated junction temperature and the thermal power of an individual LED according to:

$$R_{th,j\text{-}b,real} = (T_j(1\ \text{LED}) - T_{b,max})/P_{th}(1\ \text{LED}).$$

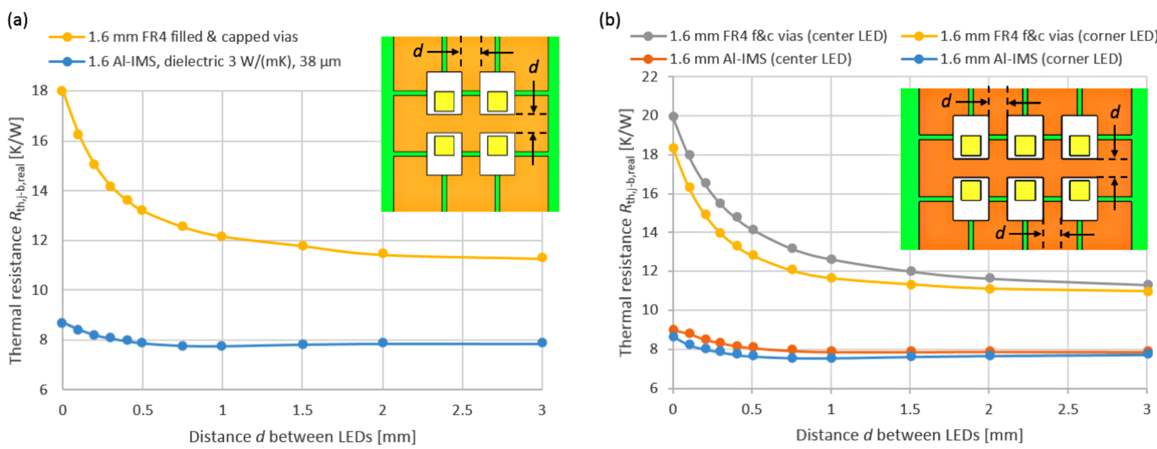


Figure 14. (a) Simulated thermal resistance $R_{th,j\text{-}b,real}$ as a function of the gap d between the LEDs for a 2x2 array configuration, (b) simulated thermal resistance $R_{th,j\text{-}b,real}$ as a function of the gap d between the LEDs for a 2x3 array configuration. The thermal resistance values in (a) and (b) refer the power of one LED.

4.3 Thermal Measurement Instructions

The use of a temperature probe may be desirable to verify the overall system design model and expected thermal performance. Different methods exist to determine the LED temperature in terms of case temperature T_c, junction temperature T_j, or phosphor temperature T_{ph}.

Table 4 lists three methods along with the expected measurement accuracy. The more accurate a measurement is, the closer T_c and T_j can be designed to their maximum allowable values as specified in the LUXEON FX2 datasheets.

Table 4. Temperature measurement methods

METHOD	ACCURACY (°C)	EFFORT	EQUIPMENT COST
Thermo sensor (e.g. thin wire thermocouple)	±2.0 to ±5.0 [1]	Low	Low
Forward voltage measurement	±0.5	High	High
Infrared thermal imaging	±2.0 to ±10.0 [2]	Medium	High

Notes for Table 4:
1. See "Temperature Probing by Thermo Sensor" for parameters determining the measurement accuracy.
2. See "Temperature Measurement by Infrared Thermal Imaging" for parameters determining the measurement accuracy.

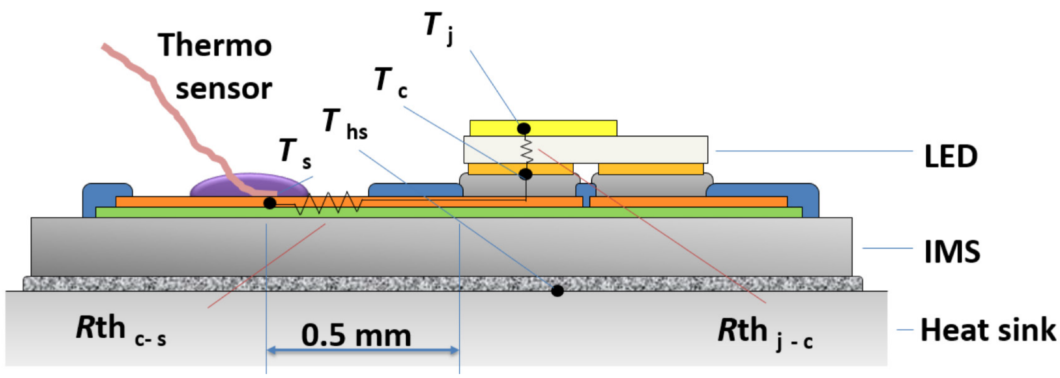


Figure 15. Temperature probing by thermo sensor

Figure 15 schematically shows the LED soldered to a PCB, including the relevant temperatures as defined for specific positions in the setup. Since the LED is directly soldered to the board, the case temperature is equal to the temperature of the solder material T_{solder}. A practical way to verify the case temperature T_c is to measure the temperature T_{sensor} on a predefined sensor pad thermally close to the case by means of a thermocouple or a thermistor as shown in Figure 15.

The case temperature can be calculated according to the following equations:

$$T_c = T_{sensor} + R_{th,c\text{-}sensor,el} \cdot P_{el}$$

$$T_c = T_{sensor} + R_{th,c\text{-}sensor,real} \cdot P_{th}$$

In these equations, T_{sensor} is the sensor temperature at the predefined location, P_{el} the electrical power of the LUXEON FX2 emitter, $P_{th} = P_{el} \cdot (1 - WPE)$ the thermal power of the LUXEON FX2 emitter, $R_{th,c\text{-}sensor,el}$ the thermal resistance between case and sensor point based on the electrical power, and $R_{th,c\text{-}sensor,real}$ the thermal resistance between case and sensor point based on the thermal power. The thermal resistances $R_{th,c\text{-}sensor,real}$ and $R_{th,c\text{-}sensor,el}$ are application specific and can be determined with help of thermal simulations and measurements. Lumileds has determined the typical $R_{th,c\text{-}sensor,real}$ and $R_{th,c\text{-}sensor,el}$ for LUXEON FX2 on different board types (see Table 5). Please refer to section 4.1 for more detailed information regarding the board design parameters. The sensor has been mounted at a distance of 0.5mm to the edge of the package as indicated in Figure 15. The accuracy of the measurement depends on the board type, the measurement accuracy of the thermocouple, and the mounting position. The temperature signal at the thermo sensor measurement point is higher for boards with large heat spreading in the top Cu layer (typically boards with low-conductive dielectric). LED boards with different configuration, design, or material from the ones given in Table 5 may require additional thermal modeling or measurements to determine the right case-to-sensor thermal resistances.

Table 5. Typical $R_{th,c\text{-}sensor,real}$ and $R_{th,c\text{-}sensor,el}$ values of different board concepts

BOARD TYPE	LUXEON FX2 PLUS COOL WHITE		LUXEON FX2 PLUS PC AMBER	
	$R_{th,c\text{-}sensor,real}$ (K/W)	$R_{th,c\text{-}sensor,el}$ (K/W)	$R_{th,c\text{-}sensor,real}$ (K/W)	$R_{th,c\text{-}sensor,el}$ (K/W)
Double-layer FR4 board with filled and capped vias	8.0	5.6	8.0	6.0
IMS with dielectric of 3 W/(mK), 38 μm thickness	5.0	3.5	5.0	3.7
IMS with dielectric of 2.2 W/(mK), 75 μm thickness	6.0	4.2	6.0	4.5

Temperature Probing by Forward Voltage Measurement

The forward voltage measurement uses the temperature dependence of the LED's forward voltage V_f. The forward voltage after switching off the thermally stabilized system is measured and analyzed, yielding information on the LED junction temperature. By using a thermal model of LUXEON FX2 or the LED junction-to-case thermal resistance as indicated in the datasheet, the case temperature T_c can be estimated. To ensure high accuracy, a precise and fast voltage measurement system is needed. In addition, the relationship between forward voltage and temperature needs to be properly characterized for each individual LED. Please contact your sales representatives for further support in this topic.

Temperature Probing by Infrared Thermal Imaging

Infrared (IR) thermal imaging can be used to measure the surface temperature/phosphor temperature of the LED or the board temperature. Lumileds does not recommend using IR measurements to estimate the LED junction or case temperature.

For an accurate determination of the absolute temperature via IR thermography, the determination of the exact emissivity value is crucial. The emissivity generally depends on material, surface properties, and temperature. It can be determined by heating up the unbiased device to a defined temperature that can be, for example, measured with a thermocouple. Then, an IR measurement can be taken of this setup, and the emissivity setting of the material of interest (typcially the phosphor or the board surface) can be adjusted to match the thermocouple reading. The obtained emissivity value can be used to evaluate the IR image of the device in operation to determine the temperature of interest. The temperature at which the emissivity value is determined should be similar to the temperature in operation that is to be measured. During IR imaging, make sure that the recorded image is not disturbed by unwanted background reflections. Due to the small dimensions of the LUXEON FX2, an imaging system with high magnification should be used in order to get a sufficient resolution of the LED in the IR image.

Note that due to losses in the phosphor converter layer, the phosphor temperature of the LUXEON FX2 is typically higher than the LED junction temperature. The absolute temperature difference depends on the drive current and on the type of phosphor.

5. Assembly Process Recommendations and Parameters

5.1 Solder Paste

For reflow soldering, a standard lead free SAC solder paste (SnAgCu) with no clean flux can be used. The majority of the Lumileds internal testing has been conducted with the Innolot solder paste, which showed reasonable reflow and voiding performance for the given settings. An Innolot based solder paste can improve thermal cycling reliability performance under certain conditions. We recommend Heraeus F640IL Innolot in combination with Al-IMS or Cu-IMS Boards. Vacuum soldering equipment can be used to achieve a lower void level. Solder paste with powder type 3 is recommended for required stencil thickness and aperture size.

5.2 Stencil Design

For the metal defined land pattern as for LUXEON FX2 (see Figure 16), Lumileds internal testing has been conducted with a stencil aperture of 90 % of the LED footprint area. For the LUXEON FX2, a stencil thickness of 120 µm (ca. 5 mil) with a type 3 paste is recommended. The corner radius of stencil aperture should be selected according to paste particle size to improve paste release.

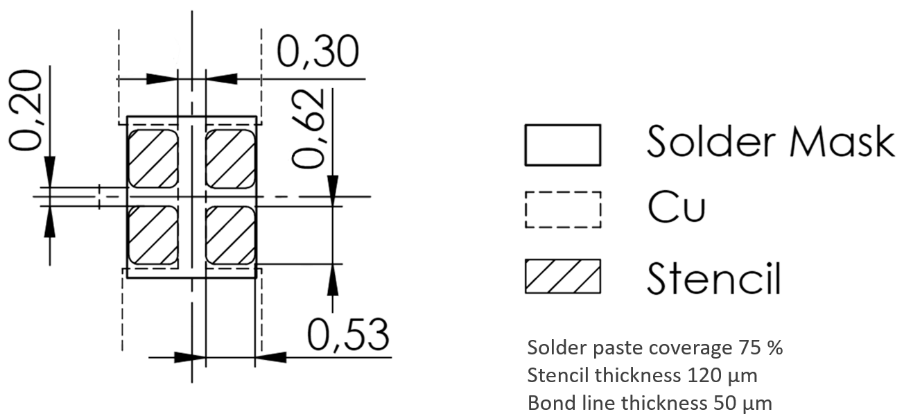


Figure 16. Stencil aperture for solder mask defined design LUXEON FX2

For the metal defined land pattern Lumileds internal testing has been conducted with a stencil aperture of 94% of the LED footprint area.

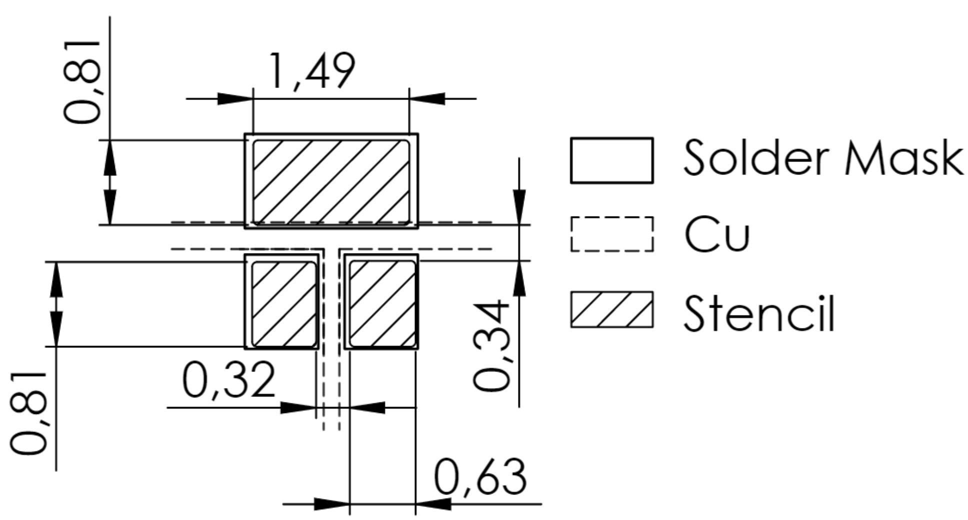


Figure 17. Stencil aperture for solder mask defined design for LUXEON FX2 Plus

5.3 Pick and Place Nozzle

The LUXEON FX2 is packed in a tape and reel with the light emitting surface facing upwards. Automated pick and place equipment provides the best handling and placement accuracy for the LUXEON FX2-LED.

Lumileds recommends taking the following general pick and place guidelines into account:

1. The pick-up area is defined in Figure 18.
2. The nozzle tip should be clean and free of any particles since this may interact with the top surface coating of the LED during pick and place.
3. During setup and the first initial production run, it is good practice to inspect the top surface of the LEDs under a microscope to ensure that there are no accidentally damaged by the pick and place nozzle.
4. To avoid any mechanical overstress, it is a good choice to use soft material for pickup. Rubber nozzles are available from various suppliers.
5. Ceramic nozzle can be used as low mass nozzles.
6. Lower Z-axis velocity at the point of board contact to avoid LED damage.

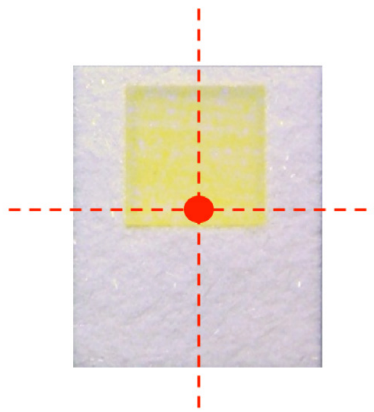


Figure 18. Pick-up position for LUXEON FX2 Plus LED

Since LUXEON FX2 has no primary optics or lens which can act as a mechanical enclosure protection for the LED chip, the pick-up and placement force applied to the top of the package should be minimized and kept well controlled.

Picking the component out of the carrier tape should be performed from a defined height position and should not apply forces to the component and carrier tape, as this may damage the component. The LUXEON FX2 is packed in a recess of the carrier tape, and the nozzle geometry must be selected accordingly to not get in contact with carrier tape (see Figure 19).

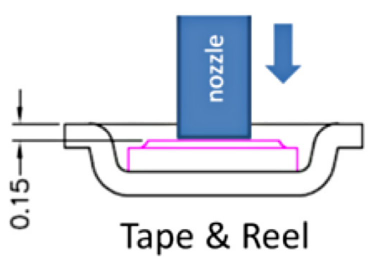


Figure 19. Pick-up from carrier tape

For the LUXEON FX2, a standard pick and place nozzle can be used, as shown in Figure 20a, 20b and 20c.

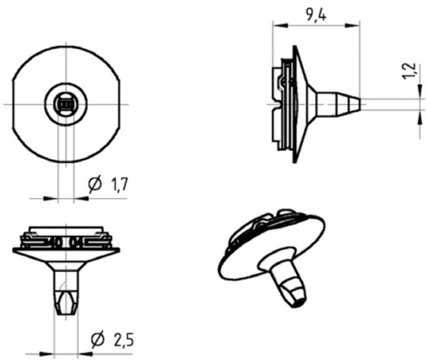


Figure 20a. ASM Siplace nozzle recommendation for LUXEON FX2

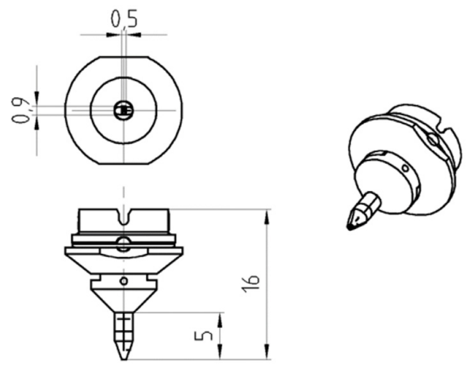


Figure 20b. Alternative ASM Siplace nozzle recommendation for LUXEON FX2

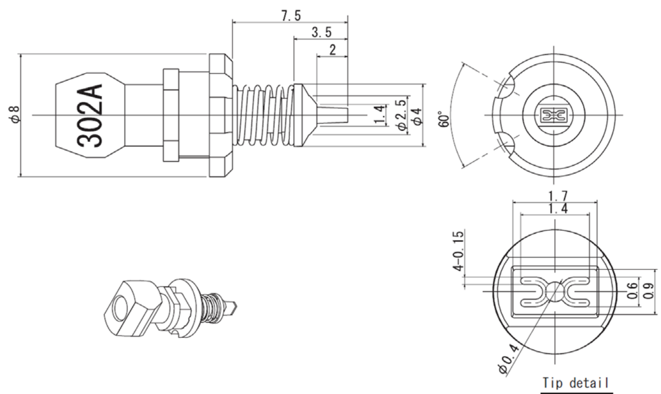
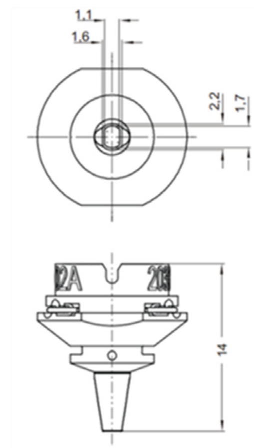


Figure 20c. Yamaha nozzle recommendation for LUXEON FX2

Table 6. ASM Siplace nozzle recommendation for LUXEON FX2

STANDARD NOZZLE (ORDER CODE)		03054253-02	
Supplier	ASM Siplace	ASM Siplace (alternative)	Yamaha
Nozzle form	Rectangular	Rectangular	Rectangular
Material: Housing / Tip	Vectra/Ceramic ESD able	Vectra/Ceramic ESD able	Vectra/Ceramic ESD able
P&P Head	4004	2033 CPP	302A
Name	Nozzle Type 4004	Nozzle Type 2033	Nozzle Type 302A
Measurements [mm]	A = 1.7 x 1.2 a = 1.3 x 0.7 L = 9.4	A = 0.9 x 0.5 a = 0.7 x 0.3 L = 16	A=1.7x0.9 a=1.4x0.6 L=7.5

Figure 21 and Figure 22 show the standard pick and place nozzles from different SMT machine vendors, which can be used to handle the LUXEON FX2 Plus.



03054923-01

Figure 21. ASM Siplace nozzle recommendation for LUXEON FX2 Plus

Table 7. ASM Siplace nozzle recommendation for LUXEON FX2 Plus

STANDARD NOZZLE (ORDER CODE)	03054923-02
Supplier	ASM Siplace
Nozzle form	Rectangular
Material: Housing / Tip	Vectra A230/TPU ESD able
P&P Head	2033 CPP
Name	Nozzle Type 2033
Measurements [mm]	A = 2.2 x 1.6 , a = 1.7 x 1.1, L = 14

Vendor	Juki
P&P Head	504
Type	Round
Material	Tungsten Steel
D-outer	1.5 mm

Figure 22. Juki machine nozzle recommendation for LUXEON FX2 Plus

5.4 Placement Force

In order to avoid any damage of the LED and minimize squeeze-out of solder paste, placement process needs to be tightly controlled. Lumileds recommends using low placement forces or a Z-height controlled placement during the pick and place process. The force during pick and place should not exceed 2.0 N. An additional large dynamic peak force occurs if the LED is placed with high Z-axis velocity at the point of touching the board and if the nozzle mass is high. Under worst case conditions, the LED can be damaged. For example, if large particles are underneath the LED (see Figure 23). Lower the Z-axis velocity if needed.

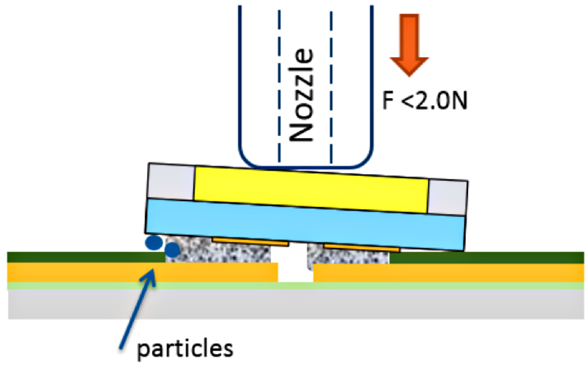


Figure 23. LED touching the board during pick and place can worst case damage the LED

5.5 Feed System

Pick and place machines are typically equipped with special pneumatic or electric feeders to advance the tape, that contains the LEDs. The indexing step in the pick and place process may cause some LEDs to accidentally jump out of the pocket tape or may cause some LEDs to get misaligned inside the pocket tape, resulting in pick-up errors. Depending on the feeder design, minor modifications to the feeder can substantially improve the overall pick and place performance of the machine and reduce/eliminate the likelihood of scratch or damage to the LEDs. The pick-up position should be right after the cover tape peel off. Do not leave index positions uncovered between peel off and pick position. This will prevent the LEDs from tilting over or jumping out when indexing. The cover tape peeling angle, relative to the tape, should be small to reduce the vertical pulling force during indexing (see Figure 24).

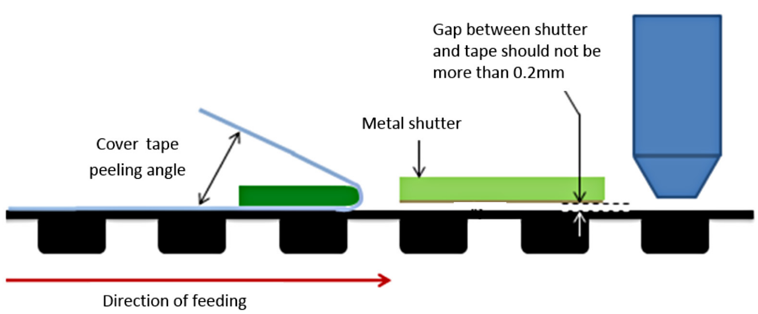


Figure 24. Pick position and cover tape peeling

5.6 Reflow Profile

The LUXEON FX2-LED is compatible with standard surface-mount and lead-free reflow technologies. This greatly simplifies the manufacturing process by eliminating the need for adhesives and epoxies. The reflow step itself is the most critical step in the reflow soldering process and occurs when the boards move through the oven and the solder paste melts, forming the solder joints. To form good solder joints, the time and temperature profile throughout the reflow process must be well controlled. A temperature profile consists of three primary phases:

1. Preheat: the board enters the reflow oven and is warmed up to a temperature lower than the melting point of the solder alloy.
2. Reflow: the board is heated to a peak temperature above the melting point of the solder, but below the temperature that would damage the components or the board.
3. Cool down: the board is cooled down rapidly, allowing the solder to freeze, before the board exits the oven.

As a point of reference, the melting temperature for SAC 305 is 217 °C, and the minimum peak reflow temperature is 235 °C.

Lumileds successfully utilized the reflow profile in Figure 25 and listed in Table 8 for LUXEON FX2.

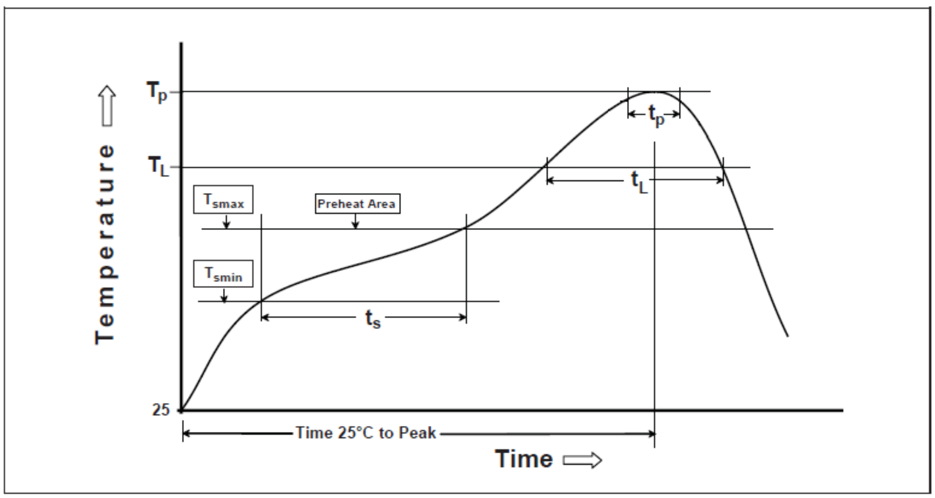


Figure 25. Reflow profile definition according to JEDEC J-STD-020E

Table 8. Temperature measurement methods

PROFILE FEATURE	TYPICAL VALUE	MAXIMUM ACC.TO JEDEC J-STD-020E
Preheat Minimum Temperature (T_{smin})	150 °C	150 °C
Preheat Maximum Temperature (T_{smax})	200 °C	200 °C
Preheat Time (t_{smin} to t_{smax})	100 seconds	60 to 120 seconds
Ramp-Up Rate (T_{smax} to T_p)	2 °C / sec. avg.	3°C / second
Liquidus Temperature (T_L)	217 °C	217 °C
Time Maintained Above Temperature T_L (t_L)	60 seconds	120 seconds
Peak/Classification Temperature (T_p)	240 °C	260°C
Time within 5°C of Actual Peak Temperature (t_p)	20 seconds	30 seconds
Maximum Ramp-Down Rate (T_p to T_L)	2.5 °C/sec. avg.	6°C/second
Time 25°C to Peak Temperature	310 seconds	480 seconds
Nitrogen Atmosphere (O_2)	<1000ppm	

Note: All temperatures refer to the application Printed Circuit Board (PCB), measured on the surface adjacent to the package body.

Things to watch for after reflow should include:

1. Solder voids — perform x-ray inspection
2. Solder bridge between anode and cathode
3. Solder balling
4. Any visible damage, tilt or misplacement of LED
5. Any contamination on light emitting area — this may impact the light output extraction or cause color shift
6. Functional test (open/short)
7. Current test, e.g. V_f at 1 mA ≥ 2.0 V

5.7 Reflow Accuracy

Lumileds performed tests for position accuracy after reflow (see Figure 26 and Table 9). Results may vary based on printed circuit board quality and used assembly process.

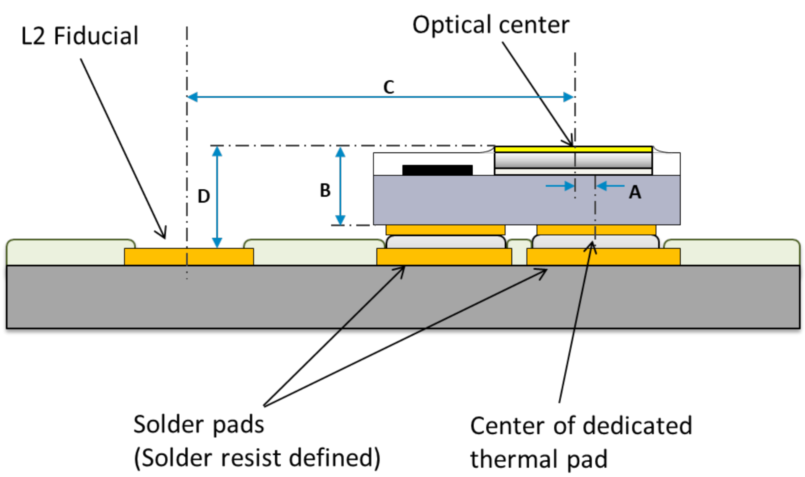


Figure 26. L1 and L2 tolerance definition. Exemplary cross section of LUXEON FX2 Plus

Table 9. Dimension and placement tolerances for LUXEON FX2 Plus

ITEM	DESCRIPTION	MAXIMUM VALUE (5σ)	TYPICAL VALUE
A	L1: Optical center to back-side metal X/Y	±50 µm	
B	L1: Total thickness Z	±75 µm	
C	L2: Optical center to L2 fiducial, X/Y		±50 µm
D	L2: Optical center to L2 fiducial, Z		±75 µm

Note: Typical values given are derived from sample based assembly tests performed at Lumileds and calculated for 5 Sigma.

5.8 Board Handling and Bending

The LED package handling precaution, as described in section 2.2 "Component Handling", must also be applied when handling LED assemblies. For example, bending of a PCB is a common handling problem, typically seen on large boards. A printed circuit board may warp after reflow when layers with different CTE (coefficient of thermal expansion) are applied to the top and bottom of the boards. If the PCB is subsequently secured to a flat surface, a vertical force is applied to the LED package (see Figure 27).

Any deformation by mounting the board and screwing it onto a heatsink or by de-paneling, like punching-off or breaking-off, should be kept to minimum. As a general guideline, it should be at most 2 mm of vertical deflection for every 90mm of FR4 PCB length. The guideline in Figure 28 should be maintained to prevent the sapphire chip, used in the LED, from cracking and causing device failure. Reference AEC-Q200-005 for board bending test preparation.

This board bending test does not apply to solder joint reliability, as the ability of the solder joint to withstand this stress (elongation) depends on the footprint layout, solder joint thickness, solder voiding and the type of solder paste used.

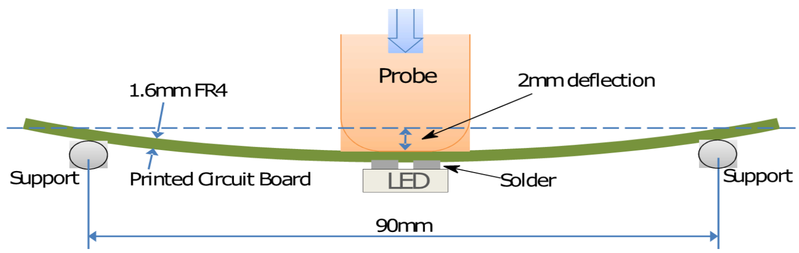


Figure 27. Maximum PCB bending guideline to prevent damage to the LED package

5.9 Packing of Assembled LUXEON FX2 Module

Finished boards must be protected against damage during transport. It is recommended to use a customized tray package, which is designed to hold the PCBs during transport (see Figure 28).

Here some general rules of best practice tray design:

1. Design the tray to avoid accidently touching the LED by manual handling. Ideally, the tray only allows one way to hold the assembly. If there are several ways to put assemblies into the tray or take them out, a strict operator discipline and clear instruction on how to safely handle the assemblies is needed.
2. It must be designed in a way that no force from the tray or packing material is applied to the LED.
3. In a stack of multiple trays, the PCB should also be secured from the top. This can be done by bottom structures of the next tray which is put on top of the stack.
4. The tray should also protect the LED against movement and shaking/vibrations during transport.

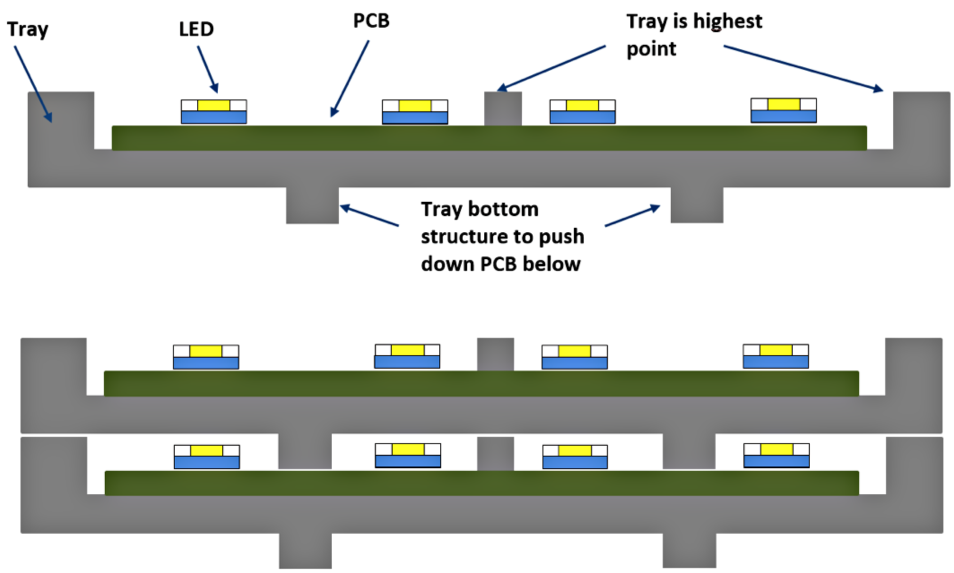


Figure 28. Schematic of a good tray design. The LEDs are protected against movement and no forces are applied to the LEDs.

6. Interconnect Reliability Parameters

The reliability of board interconnect under thermal cycling and thermal shock condition is mainly determined by thermal expansion of used materials. The LUXEON FX2 package is made of AlN which has a low CTE of ~4 ppm (coefficient of thermal expansion). The CTE mismatch between LED package and printed circuit board will lead to mechanical stress and cause solder fatigue or solder cracking. To achieve highest possible reliability the CTE of the board material should be as similar to the LED package as possible. Table 10 shows commonly used materials and their CTE.

Table 10. CTE of Common board substrate materials

MATERIAL	COEFFICIENT OF THERMAL EXPANSION (CTE) ±2.0 TO ±5.0 [1]
Sapphire (LED chip)	5-6 ppm
Solder SAC305	19-22 ppm
Copper	16.5 ppm
FR4	12-17 ppm*
Aluminium 5052	23.1 ppm
Aluminium CTE II	19 ppm
AlN	4 ppm
Al203	6-8 ppm

*Depending on laminate vendor, prepreg type, and fiber orientation

Also, the mechanical properties of solder material and solder thickness have an impact on interconnect reliability. Using a ductile material and increasing the bond line thickness will increase solder joint reliability.

The pad design of LUXEON FX2 has shown increased interconnect reliability, compared to the design of LUXEON FX2 Plus.

7. JEDEC Moisture Sensitivity Level

JEDEC has defined eight levels for moisture sensitivity, as shown in Table 11.

Table 11. JEDEC moisture sensitivity levels

LEVEL	FLOOR LIFE		SOAK REQUIREMENTS			
			STANDARD		ACCELERATED EQUIVALENT 1	
	TIME	CONDITIONS	TIME	CONDITIONS	TIME	CONDITIONS
1	Unlimited	≤ 30 °C / 85% RH	168 Hours +5 / -0	85 °C / 85% RH		
2	1 Year	≤ 30 °C / 60% RH	168 Hours +5 / -0	85 °C / 60% RH		
2a	4 Weeks	≤ 30 °C / 60% RH	696 Hours +5 / -0	30 °C / 60% RH	120 Hours +1 / -0	60 °C / 60% RH
3	168 Hours	≤ 30 °C / 60% RH	192 Hours +5 / -0	30 °C / 60% RH	40 Hours +1 / -0	60 °C / 60% RH
4	72 Hours	≤ 30 °C / 60% RH	96 Hours +2 / -0	30 °C / 60% RH	20 Hours +5 / -0	60 °C / 60% RH
5	48 Hours	≤ 30 °C / 60% RH	72 Hours +2 / -0	30 °C / 60% RH	15 Hours +5 / -0	60 °C / 60% RH
5a	24 Hours	≤ 30 °C / 60% RH	48 Hours +2 / -0	30 °C / 60% RH	10 Hours +5 / -0	60 °C / 60% RH
6	Time on Label (TOL)	30 °C / 60% RH	TOL	30 °C / 60% RH		

*Depending on laminate vendor, prepreg type, and fiber orientation

The LUXEON FX2-LED has a JEDEC moisture sensitivity level of 1. This is the best level in the industry and within the JEDEC J-STD-020D.1 standard. The customer no longer needs to be concerned about bake out times and floor life. No bake out time is required for a moisture sensitivity level of 1.

Moisture sensitivity level 1 allows the device to be reflowed three times under the specifications as described in the respective LUXEON FX2 datasheets.

8. Product Packaging Consideration – Chemical Compatibility

The package contains a silicone overcoat to protect the LED chips and extract the maximum amount of light. As with most silicones used in LED optics, care must be taken to prevent any incompatible chemicals from directly or indirectly reacting with the silicone.

The silicone overcoat is gas permeable. Consequently, oxygen and volatile organic compound (VOC) gas molecules can diffuse into the silicone overcoat. VOCs may originate from adhesives, solder fluxes, conformal coating materials, potting materials and even some of the inks that are used to print the PCBs. Some VOCs and chemicals react with silicone and produce discoloration and surface damage. Other VOCs do not chemically react with the silicone material directly but diffuse into the silicone and oxidize during the presence of heat or light. Regardless of the physical mechanism, both cases may affect the total LED light output. Since silicone permeability increases with temperature, more VOCs may diffuse into and/or evaporate out from the silicone.

Careful consideration must be given to whether the LEDs are enclosed in an “air tight” environment or not. In an “air tight” environment, some VOCs that were introduced during assembly may permeate and remain in the silicone overcoat.

Under heat and “blue” light, the VOCs inside the silicone overcoat may partially oxidize and create a silicone discoloration, particularly on the surface of the LED where the flux output is the highest. In an air rich or “open” air environment, VOCs have a chance to leave the area (driven by the normal air flow). Transferring the devices, which were discolored in the enclosed environment back to “open” air, may allow the oxidized VOCs to diffuse out of the silicone overcoat and may restore the original optical properties of the LED.

Determining suitable threshold limits for the presence of VOCs is very difficult since these limits depend on the type of enclosure used to house the LEDs and the operating temperatures. Also, some VOCs can photo-degrade over time.

Table 12 provides a list of commonly used chemicals that should be avoided as they may react with the silicone material. Note that Lumileds does not warrant that this list is exhaustive since it is impossible to determine all chemicals that may affect LED performance.

The chemicals in Table 12 are typically not directly used in the final products that are built around the LEDs. However, some of these chemicals may be used in intermediate manufacturing steps (e.g. cleaning agents). Consequently, trace amounts of these chemicals may remain on sub-components, such as heatsinks. Lumileds, therefore, recommends the following precautions when designing your application:

When designing secondary lenses to be used over an LED, provide a sufficiently large air-pocket and allow for "ventilation" of this air away from the immediate vicinity of the LED. Use mechanical means of attaching lenses and circuit boards as much as possible. When using adhesives, potting compounds and coatings, carefully analyze its material composition and do thorough testing of the entire fixture under High Temperature Over Life (HTOL) conditions.

Table 12. List of commonly used chemicals that may damage the silicone overcoat of the LED

CHEMICAL NAME	TYPICAL USE
Hydrochloric Acid	Acid
Sulfuric Acid	Acid
Nitric Acid	Acid
Acetic Acid	Acid
Sodium Hydroxide	Alkali
Potassium Hydroxide	Alkali
Ammonia	Alkali
MEK (Methyl Ethyl Ketone)	Solvent
MIBK (Methyl Isobutyl Ketone)	Solvent
Toluene	Solvent
Xylene	Solvent
Benzene	Solvent
Gasoline	Solvent
Mineral spirits	Solvent
Dichloromethane	Solvent
Tetracholoromethane	Solvent
Castor oil	Oil
Lard	Oil
Linseed Oil	Oil
Petroleum	Oil
Silicone Oil	Oil
Halogenated Hydrocarbons (containing F, Cl, Br elements)	Misc.
Rosin Flux	Solder Flux
Acrylic Tape	Adhesive

About Lumileds

Companies developing automotive, mobile, IoT and illumination lighting applications need a partner who can collaborate with them to push the boundaries of light. With over 100 years of inventions and industry firsts, Lumileds is a global lighting solutions company that helps customers around the world deliver differentiated solutions to gain and maintain a competitive edge. As the inventor of Xenon technology, a pioneer in halogen lighting and the leader in high performance LEDs, Lumileds builds innovation, quality and reliability into its technology, products and every customer engagement. Together with its customers, Lumileds is making the world safer, better and more beautiful—with light.

To learn more about our lighting solutions, visit lumileds.com.

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