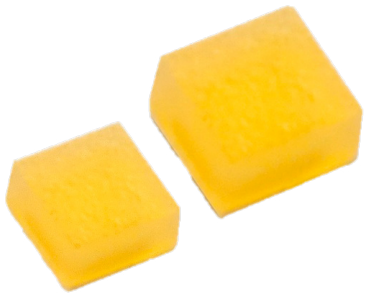
LUMILEDS

GENERAL ILLUMINATION

LUXEON FlipChip White

Assembly and handling information



Introduction

This application brief addresses the recommended assembly and handling guidelines for LUXEON FlipChip White. Proper assembly and handling, as outlined in this application brief, ensures high optical output and the long-term performance of LUXEON FlipChip White.

Scope

The assembly and handling guidelines in this application brief apply to the following products with the part number designation as described below.

LUXEON FlipChip White (LxF2-abcdyz0000000)

Where:

x - designates packaging option (0 for bin sheet, 1 for tape and reel)

ab - designates nominal ANSI CCT (27 for 2700K, 30 for 3000K, 40 for 4000K)

cd - designates minimum CRI performance (70 for 70 CRI, 80 for 80 CRI)

yz - designates size (10 for LUXEON FlipChip White 10, 05 LUXEON FlipChip White 05)

In the remainder of this document the term LUXEON FlipChip refers to any products in the LUXEON FlipChip White product family. LUXEON FlipChip White 10 refers to the larger package outline (1.38 x 1.38 mm^2) while LUXEON FlipChip White 05 refers to the smaller package outline (1.08 x 1.08 mm^2).

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1. LUXEON FlipChip Details

1.1 Description

The top of LUXEON FlipChip is encapsulated with silicone (Figure 1) that protects the underlying phosphor layer. The solder pads on the bottom of LUXEON FlipChip are finished with under-bump metallization (UBM), consisting of a standard copper-nickel-gold (Cu-Ni-Au) layer, with gold as pad finish. LUXEON FlipChip is not designed to be attached with silver epoxy material. Each LUXEON FlipChip configuration has a unique anode marking, which is best viewed with a 20X optical microscope (see Figure 2). LUXEON FlipChip is designed to be reflowed onto a Printed Circuit Board (PCB) using a standard surface mount technology (SMT) process (Figure 3).

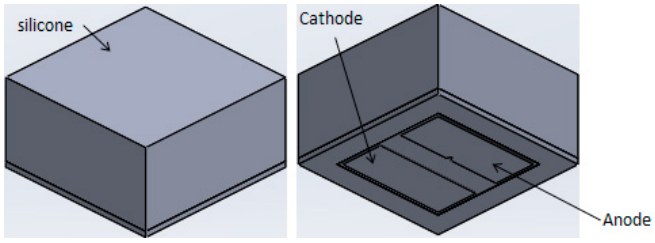

Figure 1. Image rendering of LUXEON FlipChip White 10 package. LUXEON FlipChip White 05 has similar construction but different anode marking appearance.

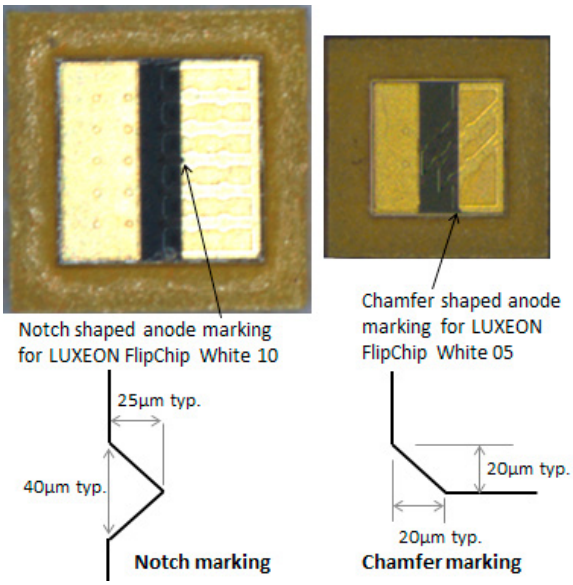

Figure 2. Anode markings on LUXEON FlipChip White 10 (left) and LUXEON FlipChip White 05 (right) and their corresponding typical dimensions.

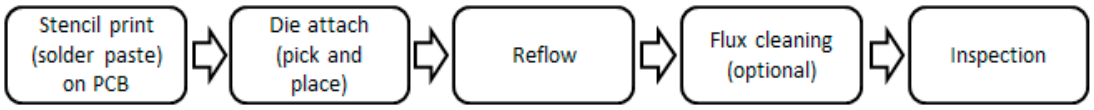

Figure 3. Generic SMT process flow.

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1.2 Optical Property

LUXEON FlipChip emits light from all the surfaces of the package as shown in Figure 4. More than 28% of the total light is emitted downward or behind the package. An example of a light up image of LUXEON FlipChip is shown in Figure 5.

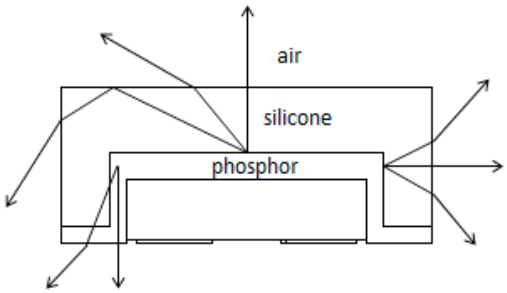

Figure 4. Illustration of ray tracing from LUXEON FlipChip. Note that the light is coming out from all sides of the cube.

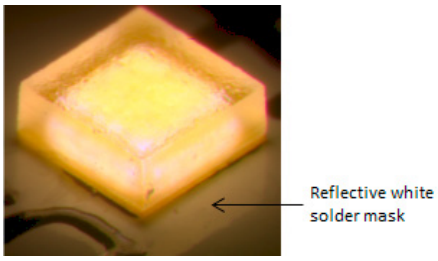

Figure 5. Actual light up images of LUXEON FlipChip White mounted on a reflective surface.

1.3 Packaging

LUXEON FlipChip is packaged and shipped on bin sheet (see Figure 6) or in tape and reel (see Figure 7). Unless specifically stated, the content in this application brief covers both configurations. Please refer to the datasheet for detailed packaging specifications.

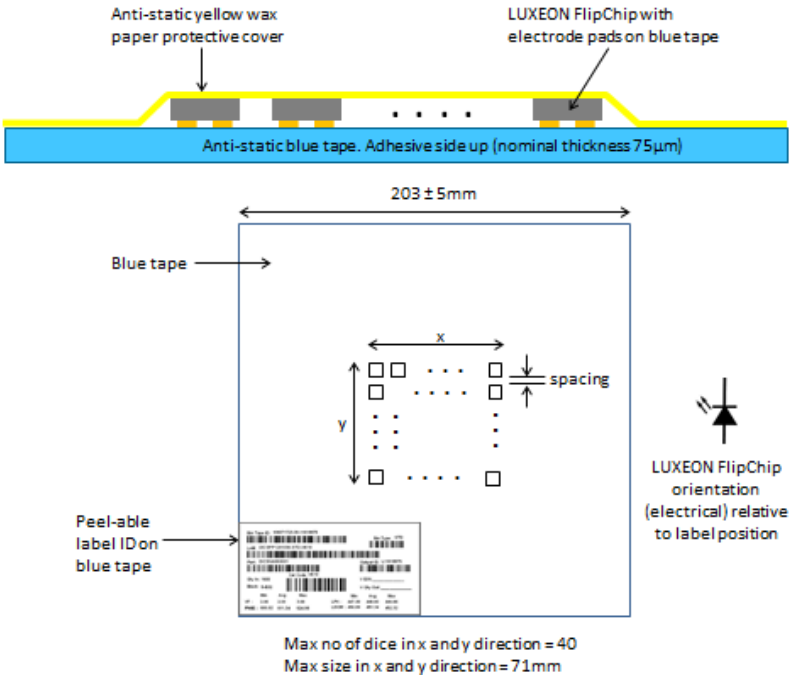

Figure 6. LUXEON FlipChip on blue tape packaging specification. The top picture shows the cross section and the bottom picture shows the LED orientation relative to the label ID. The typical spacing between units is 0.40mm and 0.70mm for LUXEON FlipChip White 10 and LUXEOn FlipChip White 05, respectively.

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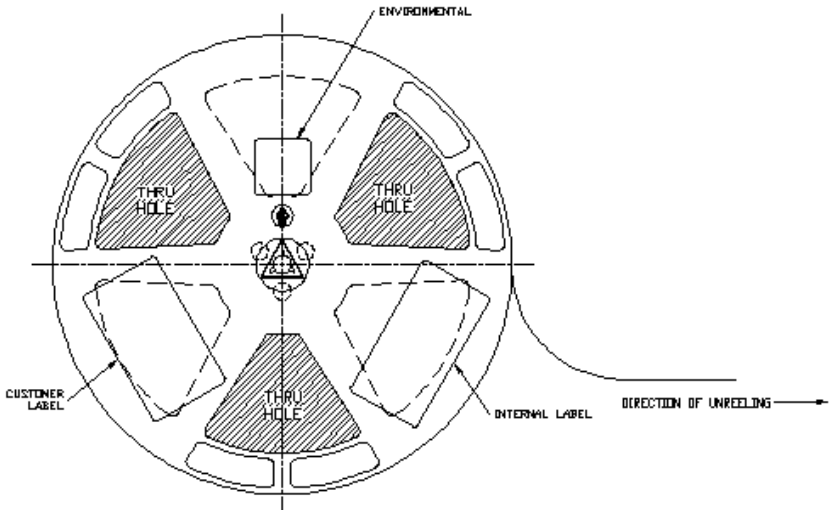

Figure 7. LUXEON FlipChip in tape and reel packaging.

1.4 Handling Precautions

LUXEON FlipChip does not include any transient voltage suppressor (TVS) chip to protect the emitter against electrostatic discharge (ESD) damage. Appropriate precautions should therefore be taken when handling this device (see Section 3.7).

Any fine dust and debris on and around the package may cause a decrease in light output. To remove dust and debris after LUXEON FlipChip is reflowed onto a PCB, use a clean air blower (10psi) at a distance of about 6" away after the TVS chips have already assembled onto the PCB to protect LUXEON FlipChip from ESD damage.

For manual handling, use ESD certified tweezers and apply minimal force on the package when picking it up. Excessive force will damage the silicone overmold of LUXEON FlipChip. The tip of ESD tweezers should be clean and made of a soft material. Handle LUXEON FlipChip only from its sides and not from the top and/or bottom to avoid damaging the p-n junction, which is located close to the bottom of LUXEON FlipChip (Figure 8).

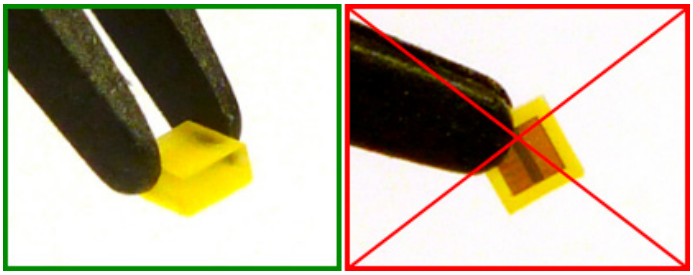

Figure 8. Correct tweezers handling of LUXEON FlipChip (left). Incorrect handling (right).

Assembled boards must not be stacked up on top of each other or placed upside down as shown in Figure 9.

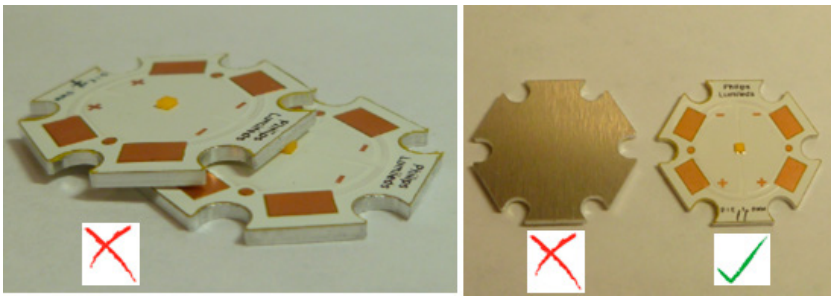

Figure 9. Do not stack assembled LUXEON FlipChip PCBs (left) and do not place assembled PCBs with the topside down on any surface (right).

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2. LUXEON FlipChip Printed Circuit Board Design

LUXEON FlipChip is engineered to be surface mounted onto a ceramic, metal-core PCB (MCPCB) or FR-4/CEM-3 substrate.

2.1 Thermal and Optical Considerations

LUXEON FlipChip has two pads that need to be soldered onto corresponding pads on the PCB. There are two important aspects to consider when designing a PCB for LUXEON FlipChip: thermal and optical performance.

To achieve optimum thermal performance, choose the appropriate PCB substrate and design (see section 2.3) for the required thermal performance and cost consideration.

To maximize optical performance (in terms of total light output), it is important to use a highly reflective solder mask around the anode and cathode pads (Figure 10). In addition, the size of the solder mask opening should not be much larger than the pads on LUXEON FlipChip. A solder mask opening, which is too large, may have a negative impact on the total light output (see section 2.9).

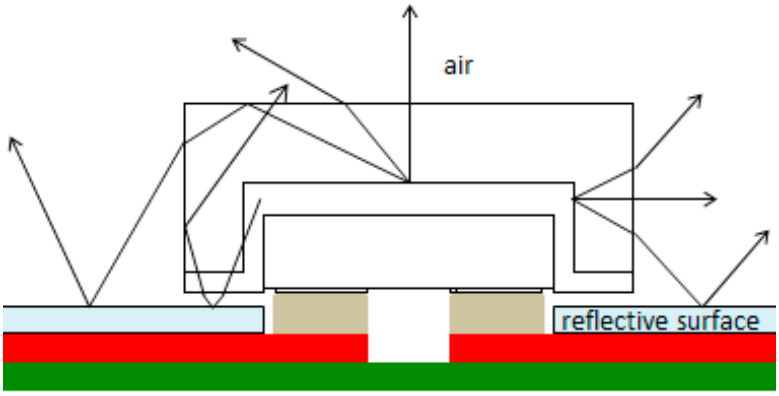

Figure 10: Examples of ray tracing of LUXEON FlipChip mounted on a PCB with reflective surface.

2.2 LUXEON FlipChip Footprint and Land Pattern

Figure 11 shows the recommended PCB footprint for LUXEON FlipChip White 10 and LUXEON FlipChip White 05. Lumileds recommends a spacing of 0.20mm between the anode and cathode traces on the PCB to prevent possible shorting during reflow. Depending on the manufacturing capabilities of the PCB supplier, one could consider adding a solder mask between the anode and cathode pads. However, Lumileds has not evaluated this option.

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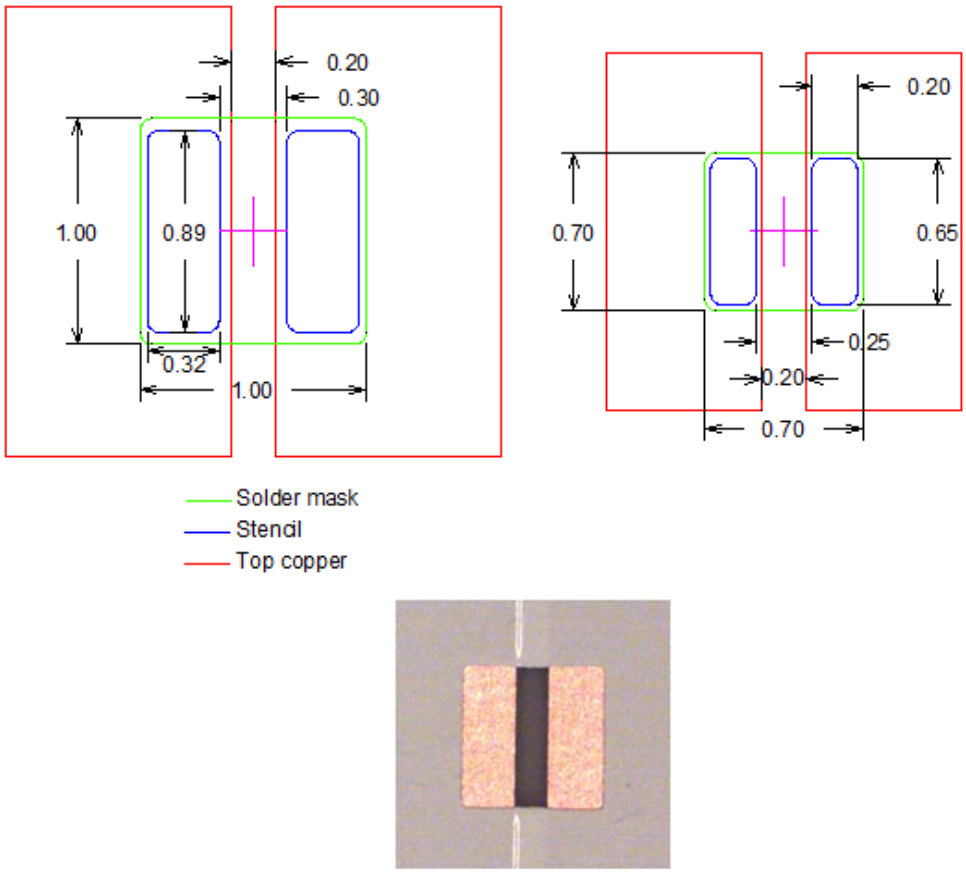

Figure 11. Recommended LUXEON FlipChip White 10 PCB footprint (top left) and LUXEON FlipChip White 05 PCB footprint (top right). Actual PCB footprint of LUXEON FlipChip White 10 is shown in the bottom. All dimensions in mm.

2.3 PCB Substrate Selection and Design

Table 1 provides a summary of various relevant performance characteristics of common PCB substrates to aid material selection.

Table 1. General PCB substrate characteristics for consideration when designing a PCB for LUXEON FlipChip.

	FR-4/CEM-3	MCPCB	CERAMIC PCB
Cost	Low to medium	Medium	High
PCB thermal conductivity performance	Very low to medium (for filled and capped vias)	Medium to excellent	High to excellent
Coefficient of thermal expansion (CTE)	Good CTE matching to LUXEON FlipChip	Moderate CTE matching to LUXEON FlipChip	Good CTE matching to LUXEON FlipChip
LED assembly packing density (thermal resistance consideration)	Suitable for low density applications with a large spacing between LEDs and/or low operating currents	Suitable for medium density applications with a moderate spacing between LEDs	Suitable for high density applications with a minimal spacing between LEDs
Mechanical assembly and handling	Easy as board does not easily break	Easy as board does not easily break	Extra precaution to prevent ceramic breakage (hard and brittle)
Supplier availability	High	High	Limited

Specific PCB design considerations for each substrate material are summarized below. For PCB thermal resistance, see section 2.4 for thermal performance based on common FR-4 and Al-MCPCB.

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Metal Core PCB

The most common MCPCB construction consists of the following layers (Figure 12):

- A metal substrate, typically aluminum. In some applications, a copper substrate may be more appropriate due to its higher thermal conductivity than aluminum (401 $Wm^{-1}K^{-1}$ versus 237 $Wm^{-1}K^{-1}$).
- Epoxy dielectric layer. This is the most important layer in the MCPCB construction as it affects the thermal performance, electrical breakdown strength, and, in some cases, the solder joint performance of the MCPCB system. The typical thermal conductivity of the dielectric layer on a MCPCB is around $2Wm^{-1}K^{-1}$. A higher value is better for good thermal performance. A thinner dielectric layer is better for thermal performance as well but can negatively impact the ability of the MCPCB to withstand a Hi-Pot (high potential) test to meet minimum electrical safety standards as required in certain lighting markets. The typical dielectric thickness layer is about 100µm. In critical applications, which need to meet strict solder joint reliability requirements, it is desirable to work with PCB manufacturers to design and engineer a low stress dielectric layer. The low stress dielectric layer can then absorb the stress generated when there is a moderate CTE mismatch between LUXEON FlipChip and the PCB substrate.
- Top copper layer. A thicker copper layer improves heat spreading into the PCB but may pose challenges for PCB manufacturers when fabricating narrow traces or spaces. A thickness of 1oz (35µm) or 2oz (70µm) is common. For optimum thermal performance, refer to section 2.4 for the amount of copper area that needs to be extended around the package outline.
- Solder mask. See requirement in section 2.6.

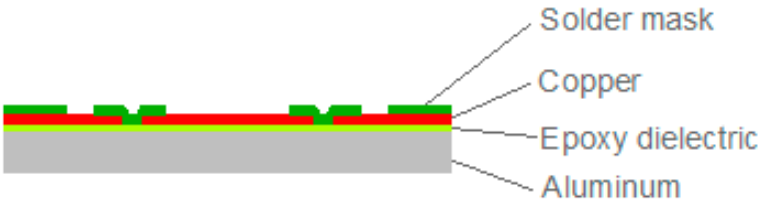

Figure 12. MCPCB typical cross section of the three-pad openings with aluminum substrate.

FR-4/CEM-3 PCB

FR-4/CEM-3 board construction consists of the following layers (Figure 13):

- FR-4 (woven fiber glass fabrics reinforced epoxy laminate, Figure 14) sheet or CEM-3 (composite epoxy material constructed from both woven and non-woven fiber glass fabrics, Figure 14). These two materials have excellent electrical insulation properties but have very poor thermal conductivity. Between these two, CEM-3 thermal conductivity is generally better than FR-4. For detail specifications of PCB, refer to a standard generated by Association Connecting Electronics Industries, (www.ipc.org), IPC-4101C "Specification for Base Materials for Rigid and Multilayer Printed Boards" standard.
- Top and bottom copper layers. To improve thermal performance, adding thermal vias will help but may require an electrically insulting thermal interface material (TIM) between an FR-4 and the heat-sink to ensure that the PCB system can meet a minimum high potential (hipot – electrical insulation barrier) test and to prevent potential device shorting over time due to breakdown of the TIM material. Two common approaches include:
    i. Open vias with plated through holes (Figure 13)
    ii. Filled and capped thermal vias (Figure 13).

  The filled and capped design gives better thermal performance than open via design but at a much higher manufacturing cost and require good surface co-planarity for small package pads such as LUXEON FlipChip. The diameter of the via, position and the quantity need to be studied to find optimum thermal performance at acceptable cost.
- Solder mask. See requirement in section 2.6.

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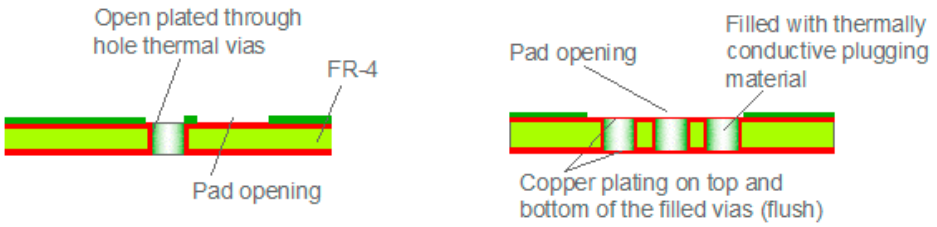

Figure 13. Left picture shows a cross section of an open via with plated through hole design with one pad opening where the LED pad is soldered onto. Right picture shows a cross section of a filled and cap via design with one pad opening. One of the LED pads is then soldered on top of the flush area where the filled and capped vias are underneath it to create direct thermal path connection between LED and bottom of PCB.

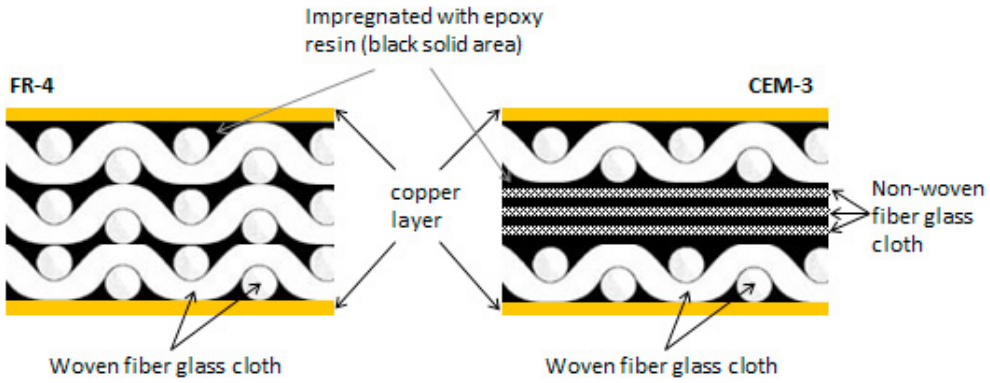

Figure 14. Cross section of a FR-4 and CEM-3 PCBs. Not drawn to scale; for illustration purposes only.

Ceramic PCB

Ceramic PCB construction consists of the following layers (Figure 15):

- Ceramic substrate. Commonly used materials are alumina (Al_2O_3) or aluminum nitride (AlN). The thermal conductivity of alumina ranges from 20 to 30 $Wm^{-1}K^{-1}$, depending on the content of the alumina material in the substrate. The thermal conductivity of aluminum nitride ranges from 170 to 230 $Wm^{-1}K^{-1}$ depending on the additives added during the ceramic manufacturing process.
- Top copper layer.
- Solder mask. White reflective solder mask is desirable to maximize light output extraction.

Ceramic has an excellent thermal conductivity and is a very good electrical insulator. Therefore, there is no need to include any epoxy dielectric layer, allowing LUXEON FlipChip to be directly attached to the ceramic via copper and solder material. This enables very tight packing of multiple LUXEON FlipChip LEDs.

However ceramic can be brittle and may require extra handling precautions during assembly and handling.

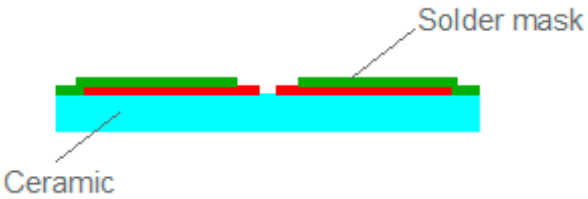

Figure 15. Cross section of ceramic based PCB. Note that there is no dielectric epoxy layer between copper (red) layer and the ceramic substrate which make ceramic PCB an excellent solution for high current operation with high density packing.

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2.4 PCB Design and Thermal Resistance

As described in section 2.3, the PCB thermal resistance (from pads of LUXEON FlipChip to the bottom of the PCB) depends on the substrate material selection and its corresponding properties. In this section, thermal simulations of a single LUXEON FlipChip on FR-4 and Al-MCPCB boards were investigated. A single sided FR-4 board (no thermal vias employed) and a 1.6mm thick Al-MCPCB with dielectric thickness of 100um were analyzed as a function of the top copper layer diameter (Figure 16) by varying the two most important PCB parameters of each PCB type as shown in Table 2.

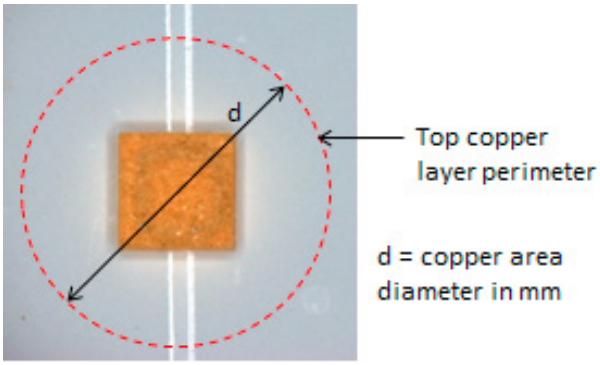

Figure 16. Diameter (d) of the top copper layer surrounding a single LUXEON FlipChip is varied in this thermal simulation study.

Table 2. PCB parameters varied in this thermal simulation study.

PCB TYPE	TOP COPPER LAYER THICKNESS (oz)	PCB BOARD THICKNESS (mm)	DIELECTRIC THERMAL CONDUCTIVITY ($Wm^{-1}K^{-1}$)
Single Sided FR-4	1	0.8	
	1	1.6	
	2	0.8	
	2	1.6	
Al-MCPCB	1		1.0
	1		3.0
	2		1.0
	2		3.0

The result for both LUXEON FlipChip White 05 and LUXEON FlipChip White 10 is shown in Figure 17. The analysis shows how much of the top copper layer needs to be extended around LUXEON FlipChip to achieve optimum PCB thermal resistance performance. For example in LUXEON FlipChip White 10, a dielectric with $3Wm^{-1}K^{-1}$ and 2oz copper layer, the top copper layer diameter should at least be 6mm or (6mm – 1.38mm)/2 = 2.31mm extending around the LUXEON FlipChip, for square shape top copper layer.

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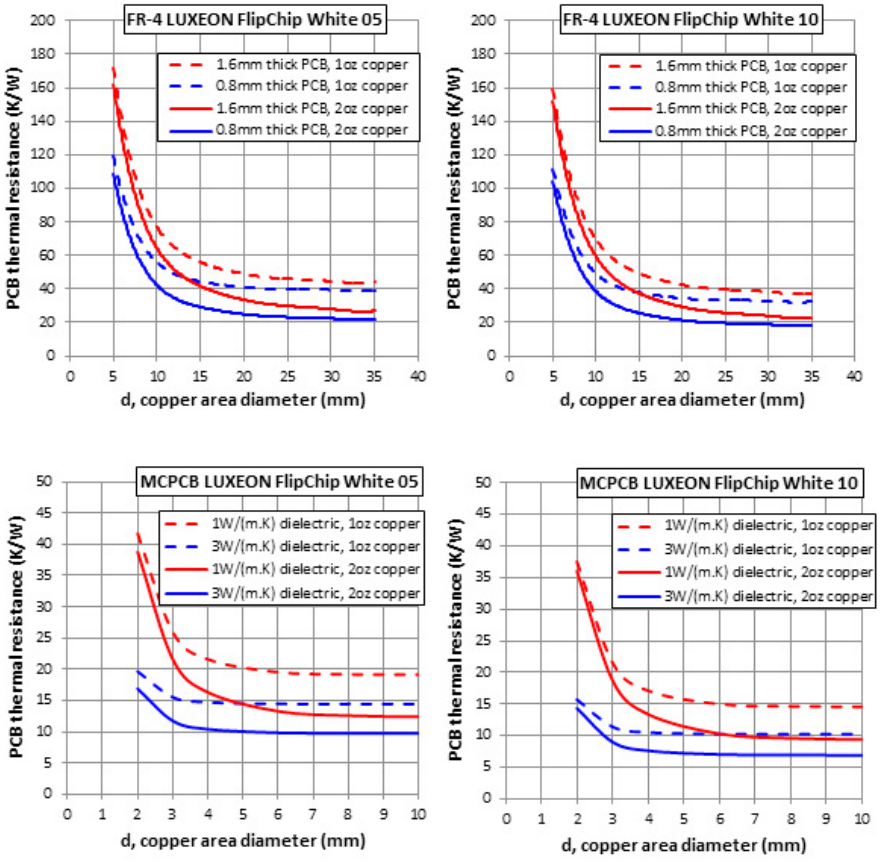

Figure 17. Thermal simulation result of a single LUXEON FlipChip mounted on various board configurations.

2.5 Surface Finishing on Copper

For small pad dimensions and pitch, Lumileds recommends using electroless nickel immersion gold (ENIG) or high temperature organic solderability preservative (OSP) on the exposed copper pads. Hot air solder leveling (HASL) should not be used because it yields poor co-planarity (leveling) and is, therefore, not suitable for fine pitch assembly with LUXEON FlipChip. In addition, HASL may yield poor solder joints, potentially resulting in open failures.

2.6 Solder Mask

A stable white solder mask finish (typically a polymer compound with inert reflective filler) with high reflectivity in the visible spectrum will typically meet most application needs. The white finish should not discolor over time (change of reflectance properties) when exposed to elevated operating temperatures, back-scattered light or pollution (photo-thermal-chemical degradation of polymers). Customers are encouraged to work with their PCB suppliers to determine the most suitable solder mask options which can meet their application needs.

Lumileds has positive testing result of the performance of Taiyo PSR-4000 LEW3 solder mask. The reflectivity of this type of solder mask can be improved by increasing the solder mask thickness.

2.7 Silk Screen or Ink Printing

Ink markings within and around the LUXEON FlipChip outline should be avoided because the height of the ink may interfere with the LUXEON FlipChip rotation, tilt and solder stencil printing process. If needed, the ink printing should be at least 1 mm away from the LUXEON FlipChip outline. Minimize the amount of ink coverage as this may have an impact to the light output.

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2.8 PCB Quality and Supplier

Select PCB suppliers that are capable of delivering the required level of quality. At a minimum the PCBs must comply with IPC standard (IPC-A-600H, 2010 "*Acceptability of Printed Boards*").

A 50µm masking tolerance between the copper trace pattern and solder mask is desirable to achieve optimum solder joint contact area using the recommended footprint as shown in Figure 11. 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, thermal performance and may increase risk of solder bridging (short) if the stencil is not properly aligned to the solder mask during printing, causing solder paste to dispense in the channel separating the anode and cathode.

Figure 18 shows an example of the solder pad size for three different misalignment levels between the copper trace pattern and the solder mask for LUXEON FlipChip White 10 using the recommended footprint in Figure 11. Large misalignment between solder mask opening and copper trace will cause one of the two copper land patterns to be smaller than the other.

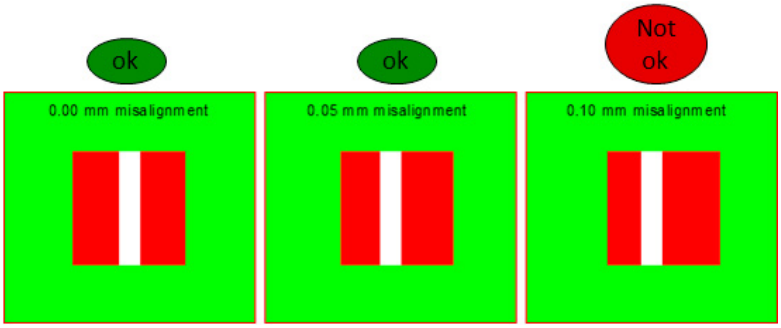

Figure 18. Diagram above shows the level of misalignment drawn to relative scale between the solder mask (green) and copper trace pattern (red) for LUXEON FlipChip 10. From left to right: no misalignment, 50um misalignment and 100um misalignment.

Depending on the PCB manufacturer capability, PCB cost consideration and customer optical performance needs, it may be necessary to increase the area of the solder mask opening. Refer to section 2.9 that discusses an experiment done to study the effect of solder mask opening on total light output.

Table 3 and Figure 19 show how the LUXEON FlipChip electrode pad contact area changes relative to the PCB copper land area when the size of the solder mask opening and the solder mask misalignment are changed. Based on Lumileds recommended footprint (Figure 11) for LUXEON FhipChip White 10, a 100µm solder mask misalignment will mean than one of the smaller electrode pads of LUXEON FlipChip has only 81% of its area in contact (via solder joint) to the copper land pattern. Assuming 25% solder void area allowed, only a total of 61% of the electrode pad area is being utilized for solder joint connection. Smaller joint area will have an impact to the overall thermal and solder joint reliability performance.

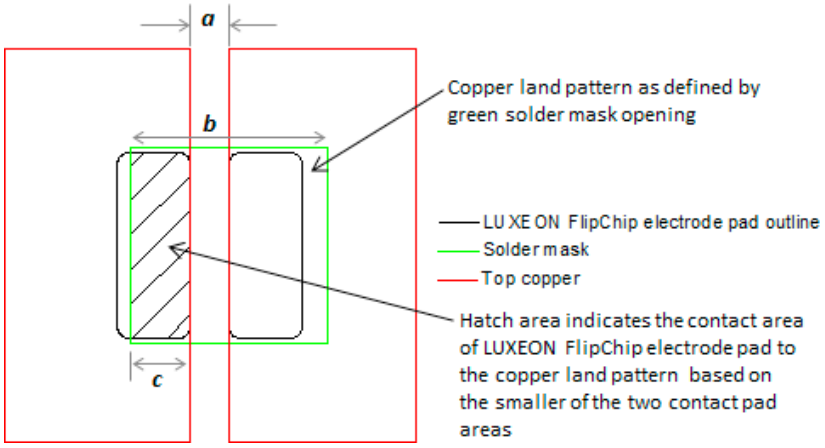

Figure 19. Definition of the parameters used in Table 3.

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Table 3. Relationship between the size of solder mask opening, solder mask misalignment and % of LUXEON FlipChip pad area in contact with the smaller copper land pattern.

	LUXEON FlipChip White 10						LUXEON FlipChip White 5					
Electrode copper spacing, ***a*** (mm)	0.20						0.20					
FlipChip pad width (mm)	0.37						0.22					
solder mask opening, ***b*** (mm)	1.00			1.10			0.70			0.80		
solder mask misalignment (µm)	0	50	100	0	50	100	0	50	100	0	50	100
copper land pattern width opening (smaller of the two), ***c*** (mm)	0.40	0.35	0.30	0.45	0.40	0.35	0.25	0.20	0.15	0.30	0.25	0.20
% LUXEON FlipChip pad area in contact with the smaller copper land pattern	100%	95%	81%	100%	100%	95%	100%	91%	68%	100%	100%	91%

2.9 Other – Effect of PCB Solder Mask Size Design on Light Output Performance

An experiment conducted in Lumileds shows that as the PCB solder mask size is increased, the light output (LOP) performance of LUXEON FlipChip White 10 (Figure 20) is affected. The white reflective solder mask is used in this study has a minimum reflectivity of 85%.

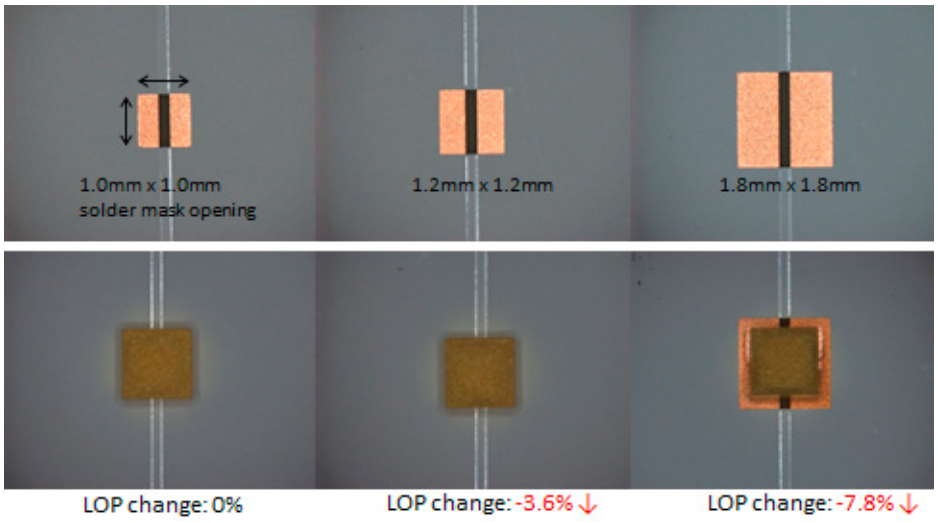

Figure 20. Impact of larger solder mask opening on light output performance relative to the 1.0mm x 1.0mm solder mask.

3. Assembly Process Guidelines

LUXEON FlipChip is designed to be compatible with traditional SMT processes (Figure 3). A SMT process typically consists SMT components (LUXEON FlipChip), PCB substrate, solder paste, die attach or pick and place machine, solder heat reflow and optional flux cleaning system. If the SMT components are ESD sensitive such as LUXEON FlipChip, ESD precautions are required (section 3.7).

3.1 Solder Paste

Lumileds successfully mounted LUXEON FlipChip LEDs on PCBs with WS-820, a water soluble semiconductor grade, SAC305 solder paste (96.5% tin, 3% silver and 0.5% copper) of type 3 (LUXEON FlipChip White 10) and 4 (LUXEON FlipChip White 05) from Alpha Advanced Materials. To maximize light output, any remaining flux residue was removed with water

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as described in section 3.6. Other SAC305-type solder pastes, such as no-clean Alpha OM-338 and OM-340, have also been successfully used to reflow LUXEON FlipChip LEDs onto a PCB using automated SMT process in Lumileds. Given the large variety of solder pastes and varying application use conditions/requirements, customers should always perform their own solder paste evaluation in order to determine if a solder paste will meet the application requirements in terms of solderability, solder joint reliability and overall long-term optical performance.

3.2 Stencil Printing

The recommended stencil thickness for LUXEON FlipChip White 10 is 4mils and for LUXEON FlipChip White 05 is 3mils. It may be necessary to make some adjustments to the stencil thickness (for examples with the use of thicker solder mask or the presence of other component where stencil thickness is critical to that component) and size opening to optimize quality of the solder joint under customer's own assembly process. There are several important factors for consideration in obtaining good quality stencil printing (Figure 21). They are:

1. The aperture (stencil opening) wall should be smooth, free of debris, dirt, and/or burrs, and have a uniform thickness throughout the stencil plate. Nano-coat the aperture walls can aid smooth release of solder paste.
2. Positional tolerance between the stencil plate and the PCB substrate must be small enough to ensure that the solder paste is not printed outside the footprint area. Hence both the stencil plate and the PCB must be secured properly.
3. During solder paste dispense, the stencil plate must be flush with the top of the solder mask. Large particles between the stencil plate and PCB may prevent a good contact.
4. The PCB substrate must be mechanically supported from the bottom to prevent flexing of the PCB during solder paste dispenses.

Using an automatic stencil printing machine with proper fiducials or guiding feature on the PCB and the stencil plate will yield the best accuracy and repeatability for the solder paste deposition process. A manual stencil printing process is not recommended for the small pad features of LUXEON FlipChip.

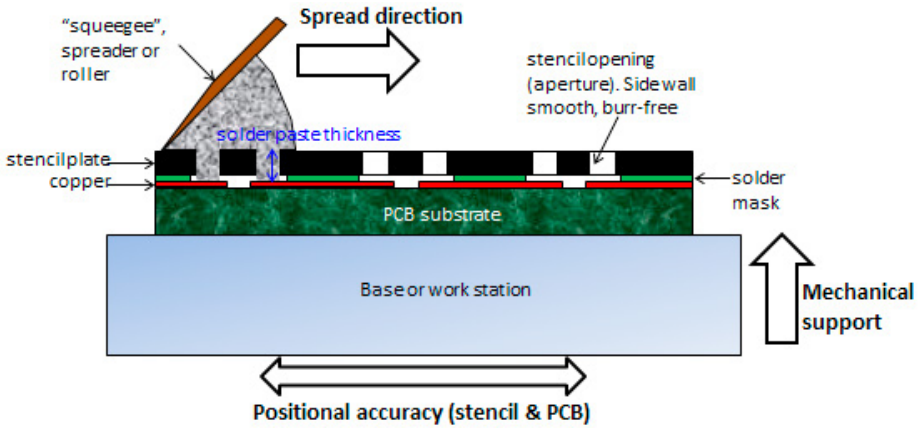

Figure 21. Stencil printing process.

Figure 22 shows some examples of a good and bad solder paste dispense process. A good reference to acceptable solder paste printing criteria can be found in IPC-7527 "***Requirements for Solder Paste Printing***" document. If the solder paste dispense process is in control, the dimensions of the solder paste on the PCB after dispense will match the size of the stencil opening. Stencil printing direction must follow the long side of the pads to ensure that the stencil opening is being completely filled with solder paste (Figure 23).

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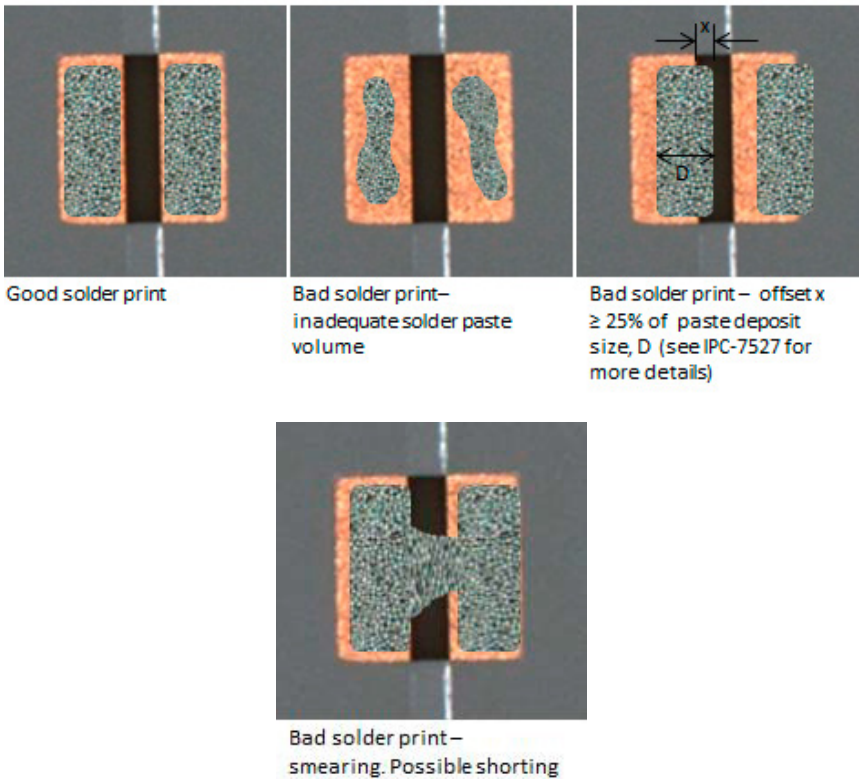

Figure 22. Examples of good and bad solder print.

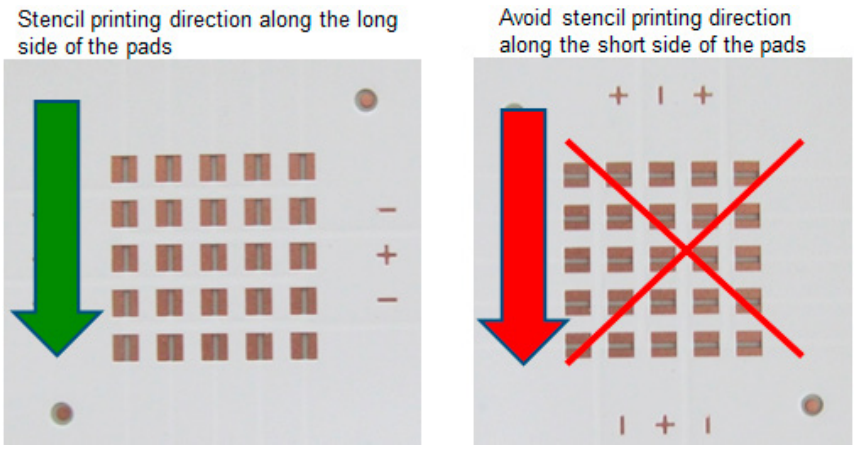

Figure 23. Orientate the PCB such that the stencil printing direction is along the long side of the pads.

3.3 Pick and Place from Blue Bin Tape Using A Die Bonder/Die Attach Machine

A typical die bonder or die attach machine (Figure 24) picks chip from a bin tape and places the chip onto a lead-frame or PCB. The medium of attachment for LUXEON FlipChip is solder paste.

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Figure 24. Typical die bonder machine (source: Besi).

There are a few important points to consider in die attach preparation for LUXEON FlipChip:

1. Die attach collet selection. Since the top of the LUXEON FlipChip is covered with silicone overmold (Shore A hardness of 80), the nozzle tip selected should not damage the silicone overmold and prevent LUXEON FlipChip from sticking to the nozzle tip. Lumileds has successfully tested a nozzle from Small Precision Tools (SPT), part number BPCT-A-030-AS which is made of a thermoplastic elastomer (with Shore A hardness of 88) with anti-stick coating (see Figure 25). This nozzle has an outer diameter (ØF) of 0.76mm and wall thickness (WT) of 0.13mm. This nozzle has been used successfully with both LUXEON FlipChip configurations.

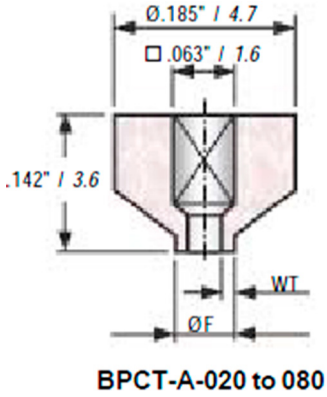

Figure 25. Nozzle tip dimension from Small Precision Tools.

2. Die attach ejector pin selection. The bottom of LUXEON FlipChip is the epitaxial material where the p-n junction is located. It is not mechanically protected and can be damaged if a sharp and hard ejector pin material is used (Figure 26). Philips recommends an ejector pin with a plastic tip radius of 100µm to minimize the risk of mechanical damage. An example of a plastic tip ejector pin is made by Micro-Mechanics (www.micro-mechanics.com), part number SEN5-T07-170-010-20 which was successfully used by Lumileds.
3. A die attach machine that can perform pattern recognition on the two bottom electrode pads will improve placement accuracy. Lumileds has successfully tested Datacon evo 2200 machine from Besi as shown in Figure 24.

Figure 27 illustrates the proper setting for the die attach collet z-height mount. Care should be taken to prevent too much collet over-travel to avoid electrical shorting of pads after reflow.

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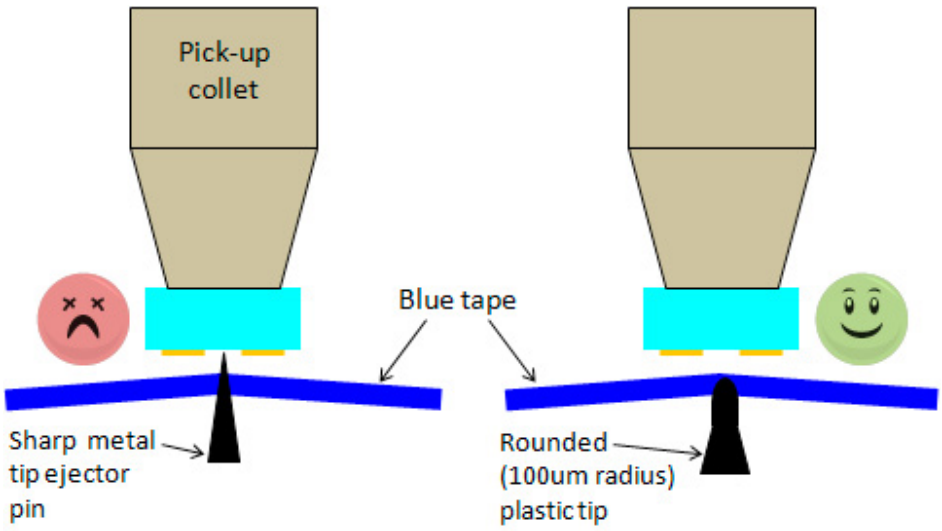

Figure 26. Sharp ejector pin tip will damage the LUXEON FlipChip (left). A rounded plastic tip minimizes damage caused by ejector pin (right).

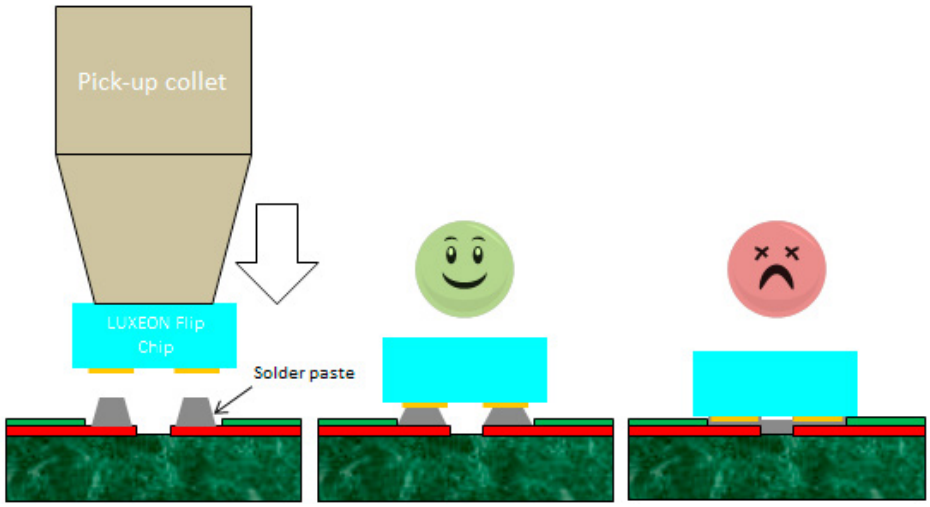

Figure 27. A proper starting point for the mounting z-height of LUXEON FlipChip is 1/3rd of the stencil thickness with reference to the top of the stencil paste, i.e. the LUXEON FlipChip should squeeze not more than a third distance into the paste. Center picture shows the optimum result for the collet height setting. Right picture shows over-travel position and may result in bridging of the solder paste on adjacent pads prior to reflow, increasing the likelihood of electrical shorts.

3.4 Pick and Place from Tape and Reel

Automated pick and place equipment provides the best placement accuracy for LUXEON FlipChip. Note that pick and place nozzles are customer specific and are typically machined to fit specific pick and place tools. Based on these pick and place experiments Lumileds advises customers to take the following general pick and place guidelines into account when handling LUXEON FlipChip:

- The nozzle tip should be clean and free of any particles since this may interact with the silicone surface of LUXEON FlipChip during pick and place.
- During setup and the first initial production runs, it is a good practice to inspect the top surface of LUXEON FlipChip under a microscope to ensure that emitters are not accidentally damaged by the pick and place nozzle.
- Observe for emitters sticking to the nozzle or emitters coming out from the pocket tape during the initial run.
- Check that the emitter orientation is correctly placed onto the PCB board.

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Nozzle dimension

The recommended nozzle inner diameter (ID) should be from 0.33mm to 0.50mm. The outer diameter (OD) should be made as small as possible (depending on nozzle material) to reduce contact area to the top of the LUXEON FlipChip and to fit within the tape and reel pocket. An example of a nozzle, which was successfully used to pick and place LUXEON FlipChip, is shown in Figure 28. In addition, the same nozzle tip as used in section 3.3 from SPT (part number: BCPT-A-030-AS) can be used on most pick and place machines via a special holder (adapter) as shown for Samsung SM421 (Figure 29 & Figure 30) and Juki KE-2080L (Figure 31 & Figure 32) machines.

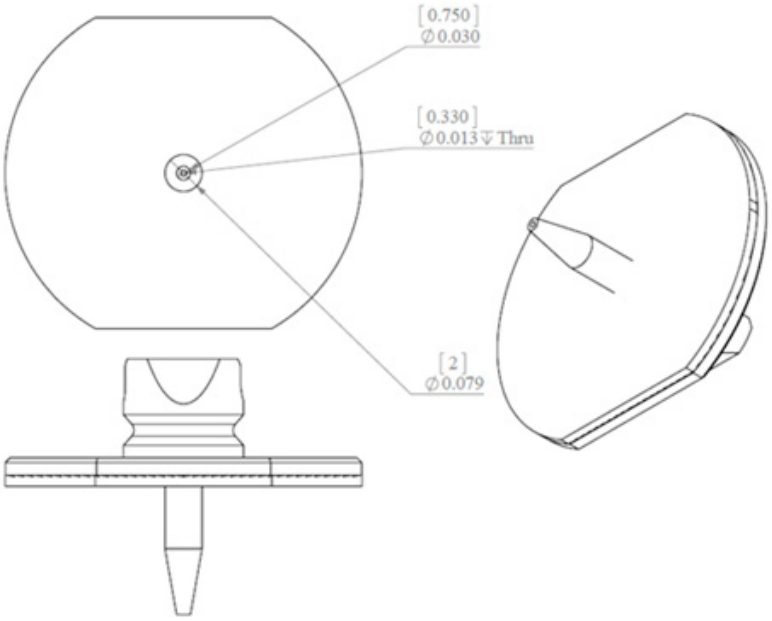

Figure 28. An example of a nozzle dimensions that is suitable for handling LUXEON FlipChip White 10 and LUXEON FlipChip White 05. It has ID/OD of 0.33mm/0.75mm.

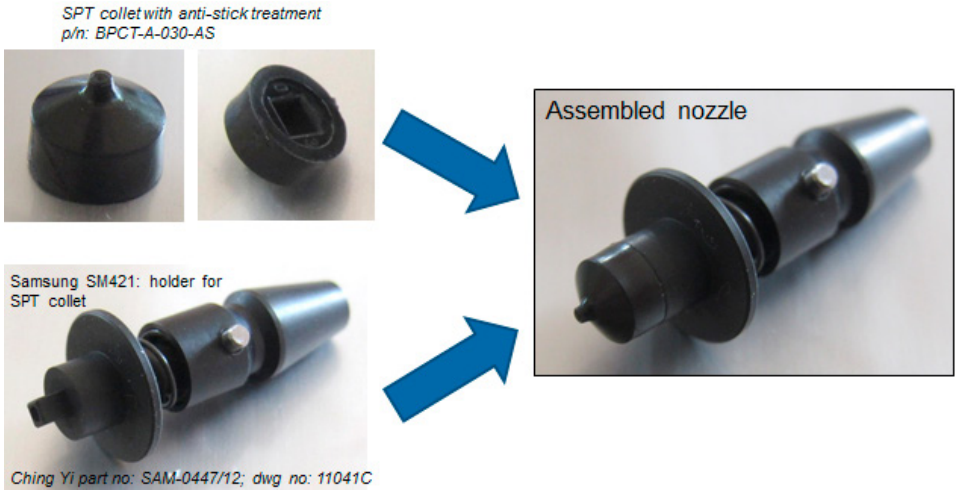

Figure 29. Samsung SM421 holder/adapter to fit SPT p/n: BPCT-A-030-AS.

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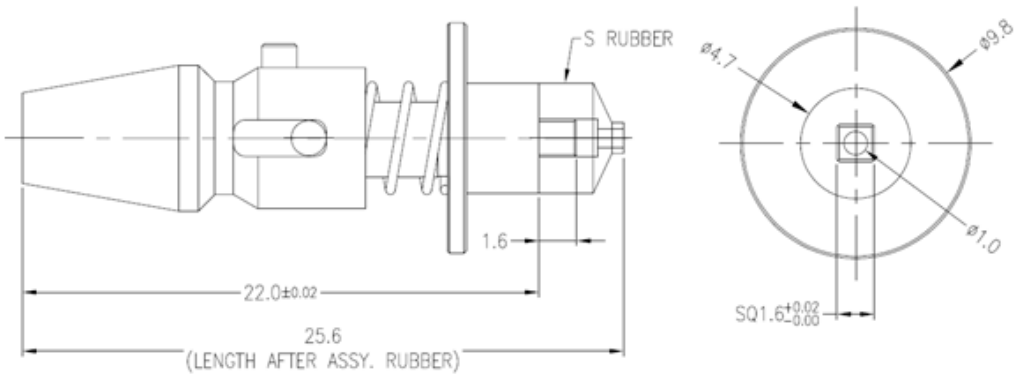

Figure 30. Samsung SM421 holder drawing for SPT collet BPCT-A-030-AS. Drawing courtesy of Ching Yi Technology Pte Ltd. Part number: SAM-0447/12, drawing no.: 11041C.

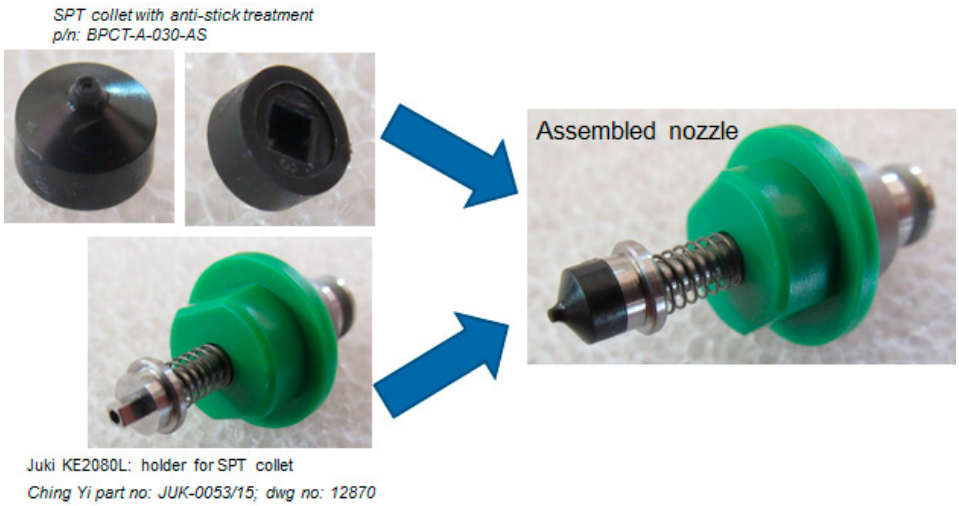

Figure 31. Juki KE-2080L holder/adapter to fit SPT p/n: BPCT-A-030-AS.

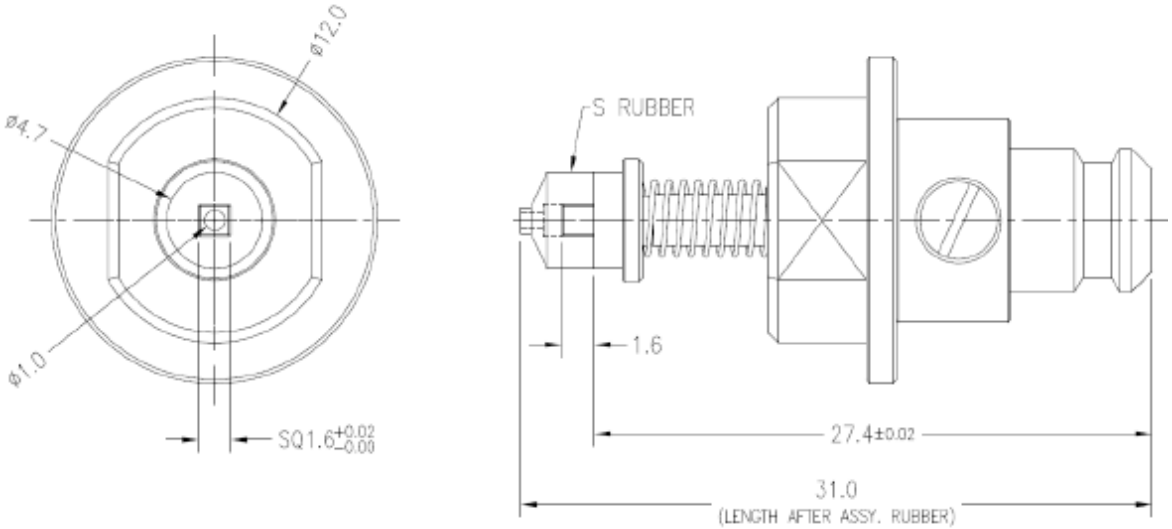

Figure 32. Juki KE-2080L holder drawing for SPT collet BPCT-A-030-AS. Drawing courtesy of Ching Yi Technology Pte Ltd. Part number: JUK-0053/15, drawing no.: 12870.

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Nozzle material

The nozzle material should be selected to achieve the desirable number of pick and place cycles and to prevent LUXEON FlipChip from sticking to the nozzle tip. Lumileds has successfully evaluated nozzles made out of the following materials:

- ceramic with anti-stick coating
- graphite

Metal nozzle is not recommended due to inconsistent release of LUXEON FlipChip.

Feeder system

Pick and place machines are typically equipped with special pneumatic or electric feeders to advance the tape containing the LEDs. In pneumatic feeders, air pressure is used to actuate an air cylinder which then turns the sprocket wheel to index the pocket tape; electric feeders, in contrast, use electric motors to turn the sprocket wheel (see Figure 33). Electric feeders often also contain a panel which allows an operator to control the electric feeder manually.

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. One such example is to cover the bottom of the metal shutter with Teflon tape such as Nitoflon from Nitto Denko if there is LED damaged during indexing (Figure 34). Also the cover tape peeling angle (Figure 34), relative to the tape should be adjusted to minimum to reduce the vertical component of the pulling force during indexing. In addition, the gap between the surfaces of the Teflon to the top of the tape should not be more than 0.4mm (Figure 34). This will prevent the LEDs from tilting over when indexing.

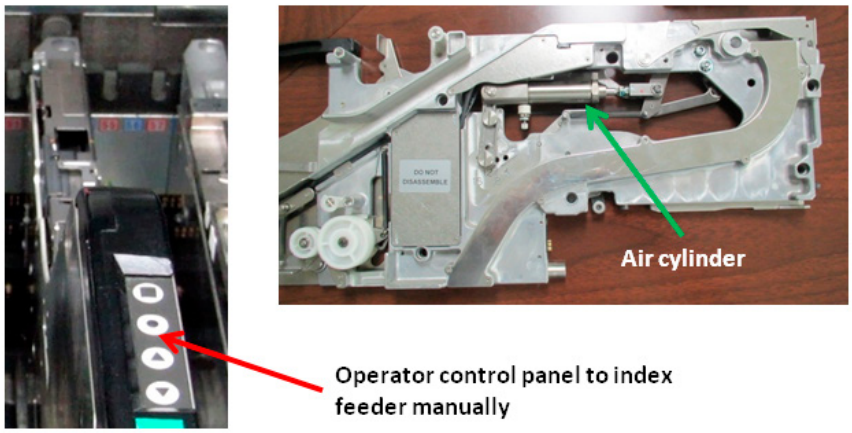

Figure 33. Examples of an electric feeder (left) and a pneumatic feeder (right) which are typically used in pick and place machines to advance the tape with LEDs.

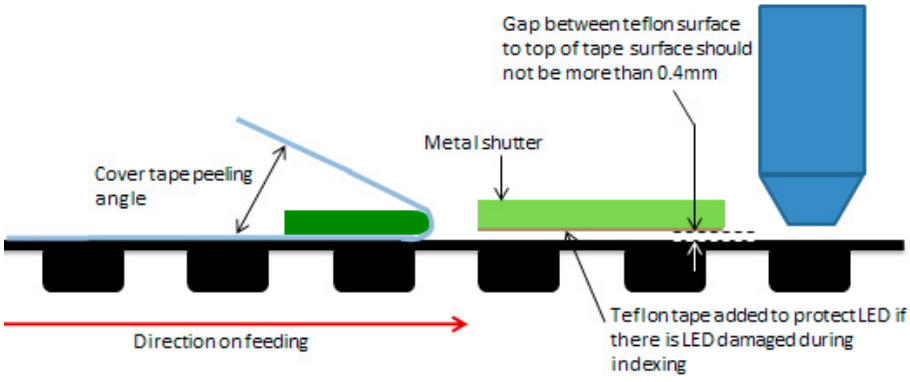

Figure 34. Simplified schematic of a feeder section where the cover tape is peeled off, metal shutter to guide LEDs from falling out or tilt over and nozzle pick up location.

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Examples of Samsung SM421 and Juki KE-2080L feeder system with pneumatic controller is shown in Figure 35.

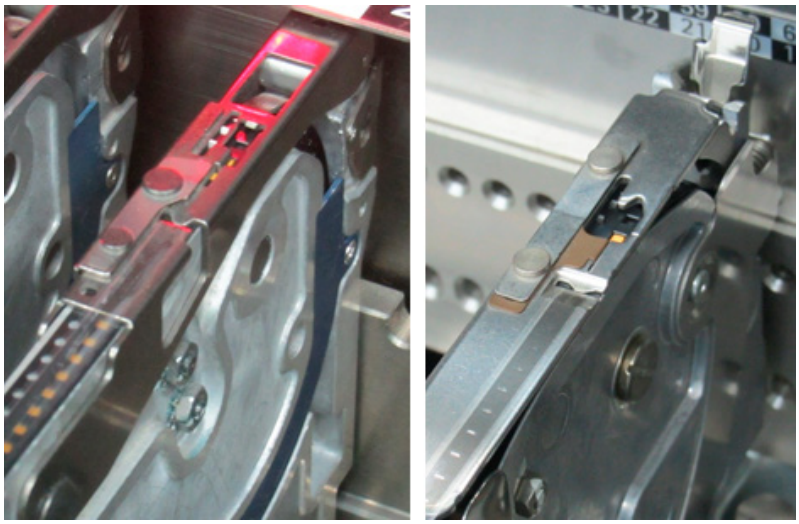

Figure 35. Left is Samsung SM421 and right is Juki KE-2080L feeders.

To minimize the jerking of components in pneumatic feeders during indexing, it may be necessary to install an air pressure control valve. In some pneumatic feeder designs, such a control valve is already integrated by the machine supplier; in others an external control valve may have to be installed (see Figure 36).

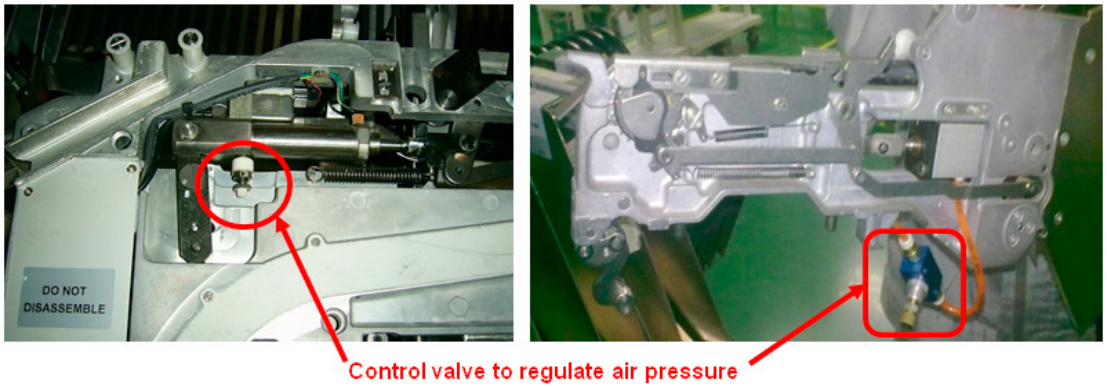

Figure 36. Pneumatic feeder with integrated air pressure control valve (left) and pneumatic feeder with air pressure control valve installed afterwards (right).

Pattern Recognition

There are two features of LUXEON FlipChip that can be used for pattern recognition during pick and place. The first one is the most common where the package outline is used. The second one is the area between the anode and cathode pads as shown in Figure 37. For this, there must be a camera mounted to view the bottom of LUXEON FlipChip.

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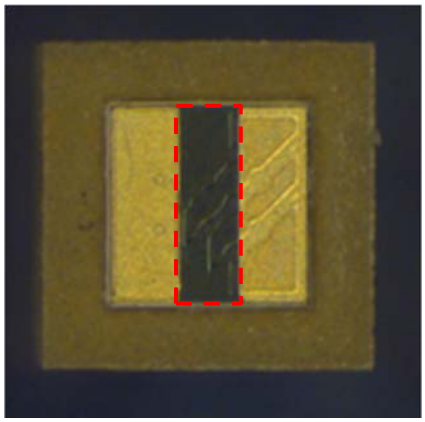

Figure 37. The area within the red dashed rectangle of the bottom of LUXEON FlipChip provides a good pattern recognition contrast.

General pick and place machine optimization for LUXEON FlipChip

As there are numerous pick and place machines in the market, below is a pick and place general setup guideline to achieve good release of LUXEON FlipChip onto PCB.

a. Vacuum – generally set to minimum level. For pick and place machine without the vacuum control and if the vacuum is too strong, check if there is a slight purge (blow) function during package release onto PCB. Note purging can blow away parts so extra care should be taken when using this option.
b. Pick-up transfer speed from reel to PCB – the shorter the better as less time for the LUXEON FCW to be under vacuum hold.
c. Z-height placement – as shown in Figure 27, the z-height starting point should be 1/3rd of the solder paste thickness. When the LUXEON FlipChip is in contact with the solder paste, it creates a certain pull force (surface tension) between the pads (solid) and the solder paste (liquid) interface. This will aid the release of LUXEON FlipChip from the tip of the nozzle. In some instances, one can also evaluate releasing the LUXEON FlipChip just above the LUXEON FlipChip onto the solder paste. LUXEON FlipChip is light and easily self-aligns during reflow as shown in Figure 39.
d. For machines with nozzle head unit assembly that accommodates multiple nozzle tips, consider reducing the number of nozzles during troubleshooting.

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Lumileds evaluated two pick and place machines: Samsung SM421 and Juki KE-2080L. The machine settings are shown in Table 4 and Table 5.

Table 3. Pick and place machine setting for Samsung SM421 machine for both LUXEON FlipChip White 10 and LUXEON FlipChip White 05.

PICK AND MOUNT INFORMATION		VISION INFORMATION	
Pick Height	0 mm	Camera No.	Fly Cam5
Mount Height	0 mm	Side	0
Delay – Pick up	30 ms	Outer	4
Delay – Place	30 ms		
Delay – Vac Off	0		
Delay – Blow On	0		
Speed – XY	1		
Speed – Z Pick Down	1		
Speed – Z Pick Up	1		
Speed – R	1		
Speed – Z Place Down	1		
Speed – Z Place Up	1		
Z Align Speed	1		
Soft Touch	Not Use		

Table 4. Pick and place machine setting for Juki Ke-2080L machine for both LUXEON FlipChip White 10 and LUXEON FlipChip White 05.

PICK AND MOUNT INFORMATION		VISION INFORMATION	
Placing Stroke	0 mm	Centering Method	Laser
Picking Stroke	0 mm	Comp Shape	Corner Square
XY Speed	Fast 2		
Picking Z Down	Fast 2		
Picking Z Up	Fast 2		
Placing Z Down	Fast 2		
Placing Z Up	Fast 2		
Laser Position	-0.57 (LUXEON FlipChip White 10) -0.30 (LUXEON Flip Chip White 05)		

3.5 Reflow

A standard SMT lead-free reflow profile can be used to reflow LUXEON FlipChip on a PCB.

Things to watch for after reflow include:

1. Solder voids – perform x-ray inspection. Keep solder void to less than 25% coverage (Figure 38).
2. Solder balling.
3. Any visible damage, tilt or misplacement of LUXEON FlipChip.
4. Change in color and/or reflectivity (i.e. dull appearance) of the solder mask. This may impact the light output extraction or cause color shift.
5. Functional test (open/short).

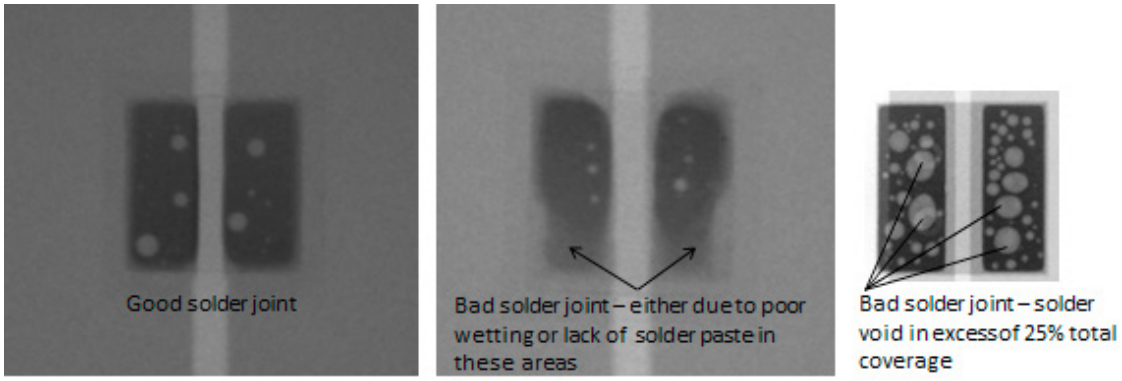

Figure 38. Example of good and bad x-ray result.

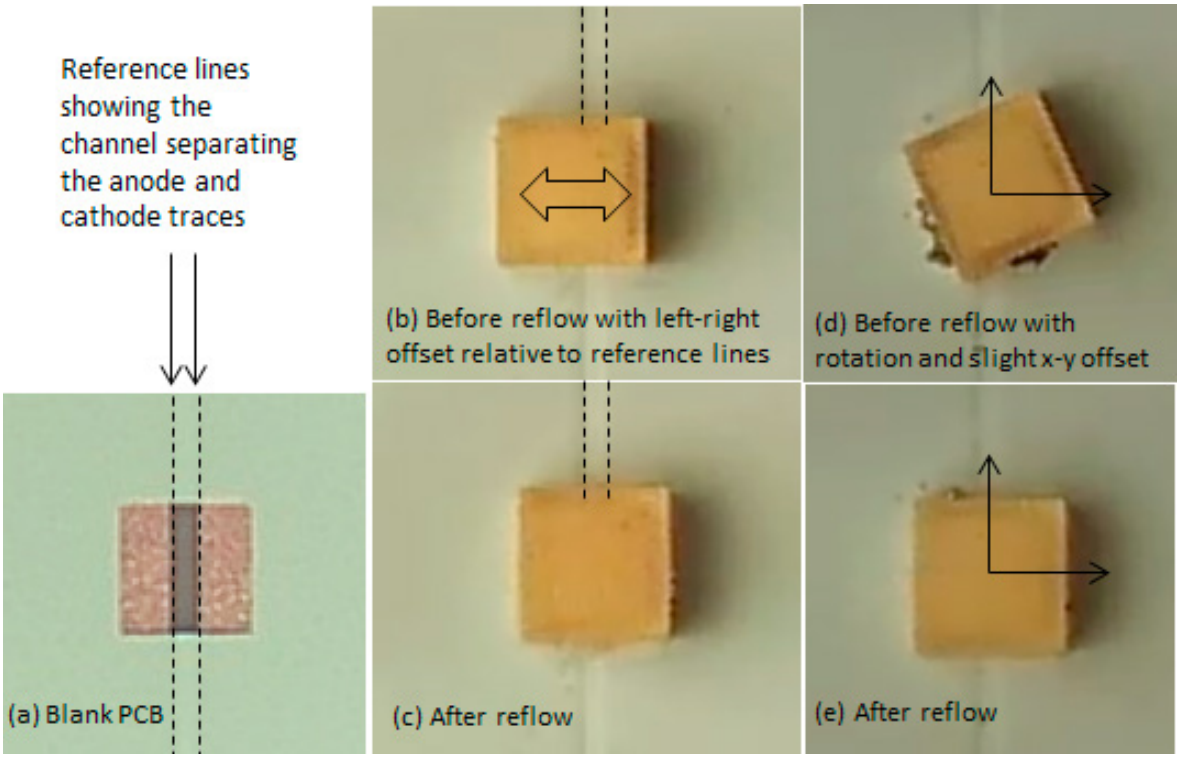

Figure 39. Examples of LUXEON FlipChip self-alignment during reflow. Figure (a) shows the reference lines. Figure (c) shows LUXEON FlipChip self-aligns after being intentionally positioned off-center to the PCB pads (Figure (b)). Figure (e) shows LUXEON FlipChip rotates to its intended orientation during reflow when intentionally being positioned as shown in Figure (d).

Reflow self-alignment

LUXEON FlipChip has been shown to self-align (Figure 39) during the reflow process if the recommended PCB footprint and automated SMT process are used, even after a deliberate misalignment was imposed during placement.

3.6 Flux Cleaning

If flux cleaning is needed, Lumileds has successfully evaluated two cleaning systems to remove flux residue from the PCB after reflow of LUXEON FlipChip with Alpha WS-820 solder paste (see section 3.1). The setup for each is described below.

Substrate cleaning system, model SCS e 124 (Figure 40): Heated water (60°C) is used for effective removal of the water soluble flux follows by spin dry and oven drying (optional).

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Ultrasonic bath model 8892 Cole-Palmer (Figure 41): With rated output power of 100W, 42kHz, fill the tank with 60°C DI water with 3 mins of ultrasonic cleaning time, follow by 1 min of running water and then oven drying.

For both systems, the size of the substrates, PCB and the overall loading factor may have an impact on the cleaning effectiveness. Customer should, therefore, always perform their own process optimization prior to adopting a particular flux cleaning process. When doing cleaning, please adhere to best ESD practices as described in section 3.7 and also consider if there are any issues on other items on the substrate or on the PCB that may be affected by water cleaning.

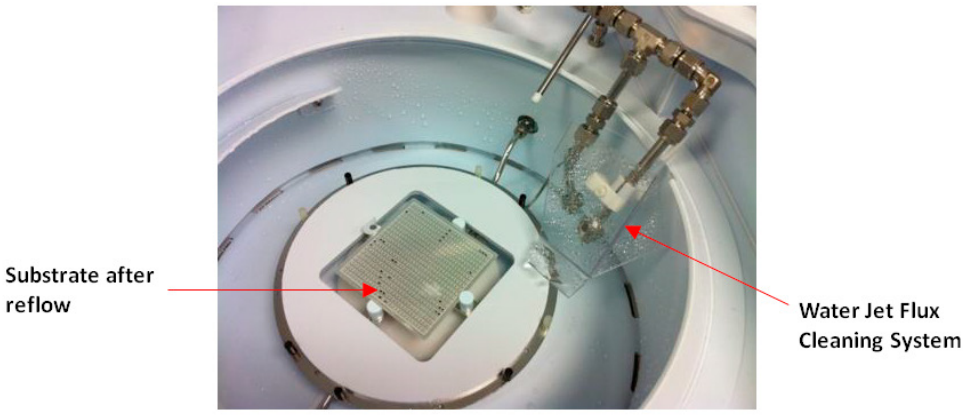

Figure 40. A water jet system can be used to remove flux residue. Shown here is substrate cleaning system, Model SCS e 124 from ULTRA t Equipment Company.

Prior to adopting a particular cleaning process in production, the effectiveness of the cleaning process can be evaluated through visual inspection of the solder mask next to the electrical pads on the PCB after shearing off the LUXEON FlipChip. There should be very little flux residue when viewed under optical microscope at 10X magnification (Figure 42).

As described in section 3.1, the need for flux cleaning is determined by the choice of solder paste and customer end product performance expectations.

Figure 41. A small scale ultrasonic bath to remove flux residue. Shown here is Model 8892 ultrasonic cleaning tank from Cole-Palmer

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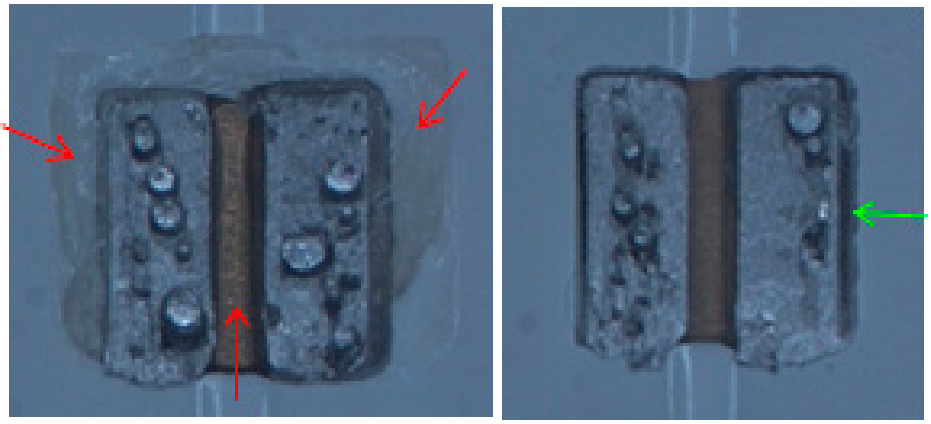

Figure 42. Images showing the top surface of PCB after LUXEON FlipChip is sheared off. Left image represents unit without any cleaning. Flux residue can be seen outside the solder pads and between the electrode pads (red arrows). Right image represents unit that has been cleaned. Small trace of flux residue around the pads is acceptable (green arrow).

3.7 Electrostatic Discharge Protection

LUXEON FlipChip does not include any transient voltage suppressor (TVS) chip to protect against ESD. A LUXEON FlipChip which is damaged by ESD may not light up at low currents and/or may exhibit abnormal performance characteristics such as a high reverse leakage current, and a low forward voltage. Latent ESD damage (no immediate failure symptom but partially damage and may degrade over time) is difficult to detect, hence safe ESD practices should be adopted during the complete handling and assembly process.

Lumileds recommends that the workplace setup and training of those operators, who handle LUXEON FlipChip, meet the ESD classification of that device per the recommendations given in JEDEC standard document JESD625B "Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices" or IEC 61340-5-1,2 and 3 documents. Some common ESD guidelines for handling LUXEON FlipChip include:

- Any handling or assembly of boards containing unprotected (no TVS) chips must be done in the designated ESD protected areas and workstations as described in JESD625B.
- Always wear a conductive wrist strap that is continuously monitored when working or handling assembled boards containing unprotected chips.
- Use an ion blower to neutralize the static discharge that may build up on the surface of the LUXEON FlipChip during storage and handling.
- Always keep unused LUXEON FlipChip in the protective ESD storage bag.

When doing flux cleaning with water, do not use DI (de-ionized) water but a water system with CO2 (carbon dioxide) bubbler when the LUXEON FlipChip is not ESD protected. Besides adding a TVS protection diode in parallel to the LED, an alternative method of ESD protection during assembly is having the LUXEON FlipChip anode and cathode temporarily at the same electrical potential by shorting both contacts. When doing this, it is important that LUXEON FlipChip has no residual charges in it (static build-up), otherwise shorting could actually damage the chips. By practicing safe ESD process during all stages of handling will minimize static build up.

Figure 43 shows three different electrical schematics to protect the LUXEON FlipChip from ESD damage. The middle option employs a permanent TVS diode while the left and right options are temporary solutions via shorting the LUXEON FlipChip electrodes. The shorted path must later be removed while still maintaining safe ESD practice during assembly and handling of LUXEON FlipChip.

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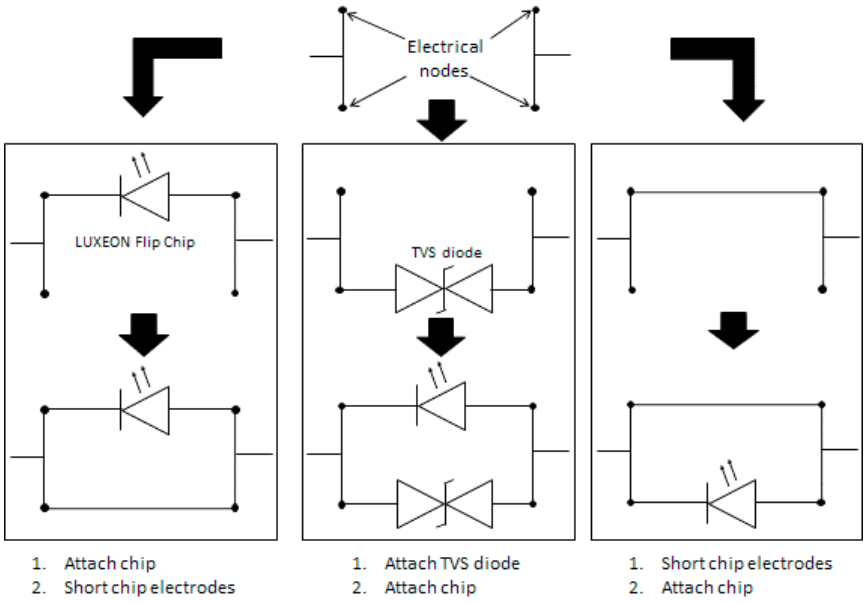

Figure 43. Electrical schematics showing three different methods of ESD protection. The middle picture provides permanent ESD protection while the left and right pictures are temporary solutions. It is important that device shorting should only be done if you know that static build up is not present by practicing safe ESD handling at all times.

3.8 Component Spacing

Based on pick and place machine with placement capability of less than ±50µm using the recommended footprint design, it is possible to achieve package to package spacing of 200µm. Packing multiple LUXEON FlipChip close together will impact the overall color and LOP performance. Please contact your regional sales or technical representative for additional information.

3.9 Board Handling and Bending

The LED package handling precaution as described in section 1.4 must also be applied when handling completed board.

Bending of PCB is another common handling problem typically seen on large boards. Unlike FR-4 or CEM-3 material, MCPCB and ceramic based PCB should not be bent due to the property of metal and ceramic substrate. For example, when a MCPCB is bent, it is difficult to return to its original flatness and would create problem when used with thermal interface material for good thermal contact.

Bending of FR-4 or CEM-3 board should be kept to minimum. As a general guideline, at most 2mm of vertical deflection for every 90mm of PCB length (Figure 44) should be maintained to prevent the InGaN chip used in LUXEON FlipChip from cracking and causing device failure. The above guideline 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.

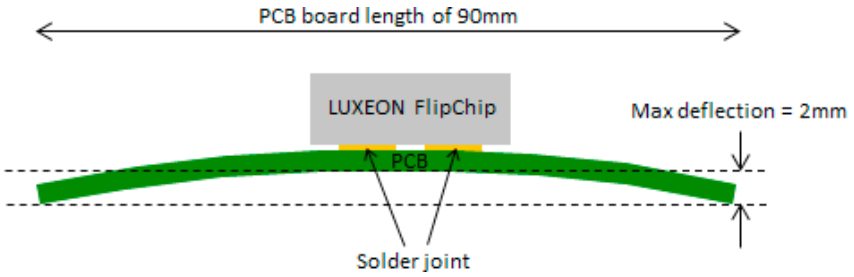

Figure 44. EMax PCB bending guideline to prevent damage to LUXEON FlipChip package. LUXEON FlipChip is placed at the mid-point of the PCB length. Not drawn to scale.

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3.10 Rework

Since rework of PCB typically involves manual processes such as heating up a section of a PCB for repair/component replacement, manual cleaning of PCB pads, manual dispensing of solder paste and manual placement of replacement component, all these can create uncontrollable processes which may yield unpredictable long term performance result. Lumileds currently does not provide any guideline on how to rework LUXEON FlipChip.

4. Thermal Measurement Guidelines

4.1 Thermal Basics

This section provides general guidelines on how to determine the junction temperature of a LUXEON FlipChip in a 1-up configuration in order to verify that the junction temperature in the actual application during regular operation does not exceed the maximum allowable temperature specified in the datasheet.

The typical thermal resistance $R\theta_{j\text{-thermal pad}}$ between the junction and the thermal pad for LUXEON FlipChip is specified in the LUXEON FlipChip White datasheet. In LUXEON FlipChip, both the anode and cathode pads act as a thermal pad which is the primary heat flow path. With this information, the junction temperature T_j can be determined according to the following equation:

$$T_j = T_{\text{thermal pad}} + R\theta_{j\text{-thermal pad}} \cdot P_{\text{electrical}}$$

In this equation $P_{\text{electrical}}$ is the electrical power going into the LUXEON FlipChip and $T_{\text{thermal pad}}$ is the temperature at the bottom of the LUXEON FlipChip pads.

4.2 Temperature Sensor Pad (T_s) and Thermocouple (TC) Attachment

In typical applications it may be difficult to measure the thermal pad temperature $T_{\text{thermal pad}}$ directly. Therefore, a practical way to determine the LED junction temperature is by measuring the temperature T_s of a predetermined sensor pad on the PCB right next to the LED package with a thermocouple (TC). The junction temperature can then be calculated as follows:

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{\text{electrical}}$$

In the above equation $P_{\text{electrical}}$ is the combined electrical power going into the LED package. The thermal resistance from junction to the T_s point, $R\theta_{j\text{-}s}$,depends on several factors such as the PCB type and construction (e.g. MCPCB dielectric layer thickness and its thermal conductivity), the location of the Ts point, type and volume of the adhesive used to attach the TC wire, and the LED emitter packing density.

To ensure accurate readings, the TC must make direct contact with the copper of the PCB onto which the LED package pad is soldered, i.e. any solder mask or other masking layer must first be removed before mounting the TC onto the PCB. The TC must be attached as close as possible to the primary heat flow path of the LED emitter pad.

More than 28% of the light energy emitted from LUXEON FlipChip is directed sideways and downward to the PCB as described in section 1.2 and 2.1. The greater amount of downward light energy from the LUXEON FlipChip inflates the TC temperature measurement reading and therefore a more suitable position has to be determined. It was found that the optimum distance between the T_s to the edge of the LUXEON FlipChip should be 2mm (Figure 45). At this distance, the temperature error introduces from the absorption of optical energy is minimized.

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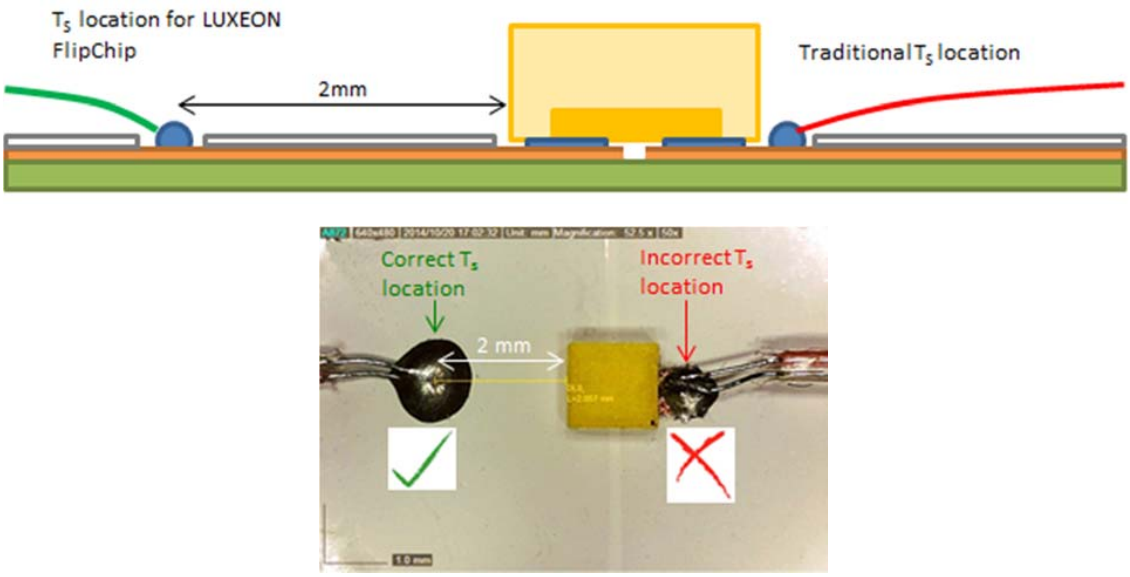

Figure 45.Top - cross-sectional view of LUXEON FlipChip and T_s locations. The T_s location should be placed 2mm away from the edge of LUXEON FlipChip (drawing not to scale). Bottom – actual setup used in the determining suitable T_s.

Lumileds has successfully used a two-part Artic Silver ™ thermal adhesive in combination with a TC wire gauge of AWG 40 or 36. Excessive dispense of thermal adhesive may impact the accuracy of the T_s temperature reading since this may increase the thermal time constant of the setup (increase in heat capacity of the thermal adhesive). The use of non-conductive thermal epoxy is not recommended since there may be a possibility of getting some epoxy residue underneath the TC wire tip and the exposed PCB copper trace which will affect the $R\theta_{j\text{-}s}$ measurement.

4.3 Thermal Measurement Result

A 1mm thick Al-MCPCB star board with 1 oz copper foil, dielectric (Nan Ya NPRCA) thickness of 0.1mm with thermal conductivity of $3W \cdot m^{-1} \cdot K^{-1}$ was used in the characterization of the T_s point thermal resistance ($R\theta_{j\text{-}s}$). The average value of $R\theta_{j\text{-}s}$ for LUXEON FlipChip White $1mm^2$ and $0.5mm^2$ and the overall MCPCB thermal resistance from LED junction to heat sink is shown in the Table 5. Use the equation below to estimate the junction temperature.

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{electrical}$$

For other PCB designs and materials, an experiment or thermal simulation may be needed to determine proper $R\theta_{j\text{-}s}$ values.

Table 5. Thermal measurement result.

LUXEON FLIPCHIP WHITE	Rth (junction to heat sink), $R\Theta_{j\text{-}hs}$	Rth (junction to T_s), $R\Theta_{j\text{-}s}$
$1mm^2$	11 K/W	10 K/W
$0.5mm^2$	21 K/W	20 K/W

5. Packaging Considerations – Chemical Compatibility

The LUXEON FlipChip 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.

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The silicone overcoat in LUXEON FlipChip 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 LUXEON FlipChip emitters 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. Under heat and "blue" light, the VOCs inside the silicone coating may partially oxidize and create an appearance of silicone discoloration, particularly on the surface of the LED where the flux energy 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 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 6 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 6 are typically not directly used in the final products that are built around LUXEON FlipChip. 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 heat sinks or on PCBs. 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.

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Table 6. List of commonly used chemicals that will damage the silicone of LUXEON FlipChip. Avoid using any of these chemicals in the housing that contains the LED package.

CHEMICAL NAME	NORMALLY USED AS
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
Tetracholorometane	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 [1]
Acrylic tape	adhesive

Note for Table 6:
1. Other than the use of no-clean solder paste qualified by customer. See section 3.1 for more details. Avoid secondary solder flux, for example when manually soldering wires close to LUXEON FlipChip, solder flux should not spit out onto the LUXEON FlipChip surface or leaving excessive secondary solder flux residue onto the PCB when operating LEDs in an air tight enclosure or poorly ventilated enclosure.

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For 100 years, Lumileds commitment to innovation has helped customers pioneer breakthrough products in the automotive, consumer and illumination markets.

Lumileds is shaping the future of light with our LEDs and automotive lamps, and helping our customers illuminate how people see the world around them.

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