Application Brief AB10

LUXEON

never before possible

Assembly Information

LUXEON® Emitter

Introduction

LUXEON® Emitters dissipate approximately 1W of thermal energy and therefore heatsinking and thermal design is critical when using LUXEON Emitters to create Power Light Sources. Standard substrate materials, such as FR4 PCB material, do not provide sufficient heat sinking for LUXEON Emitters due to their high thermal resistance. This application note focuses on designing with Metal Core Printed Circuit Board materials for optimal heat sinking, reliable operation and maximum performance.

The information herein provides the technical information required to mount LUXEON Emitters on a Metal Core Printed Circuit Board (MCPCB).

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Important Design Rules

There are four major design rules that must be considered during the design of a LUXEON array and its assembly procedure:

1. The thermal resistance from the back of a LUXEON Emitter (slug) to the ambient air must be kept to a minimum. Any heat barrier prevents the LUXEON Emitter from running at optimum performance.
2. Electrical insulation between the slug and the MCPCB is required. The slug of a LUXEON Emitter is not electrically neutral. Do not electrically connect the slug to any trace or pad on the board (see figure 5).
3. Use a thermally conductive adhesive to attach the slug to the MCPCB while minimizing the thermal resistance. The slug cannot be soldered.
4. The soldering of LUXEON Emitter terminals is limited to selective heating of the leads, such as hot-bar soldering, fiber focussed IR, or hand soldering. LUXEON Emitters cannot be soldered in infrared, vapor-phase reflow or wave soldering processes.

Metal Core Printed Circuit Board (MCPCB)

A MCPCB consists of several layers that provide both electrical connections and a low thermal resistance path to external heatsinks. Standard LUXEON arrays use a laminated MCPCB that consists of the following three layers:

- Aluminum base
- Glass-epoxy insulation layer
- Copper layer

The typical thickness of the MCPCB is 1.6mm. The base material is typically aluminum, which provides the first level of heat-sinking capacity of the array. On top of the aluminum layer is an epoxy layer that provides electrical insulation between the aluminum and the copper layer. The copper layer on top of the epoxy is used for the electrical connections and to help the lateral spreading of the heat dissipated by the LUXEON Emitter over a larger area. Figure 1 shows a cross section of a typical MCPCB.

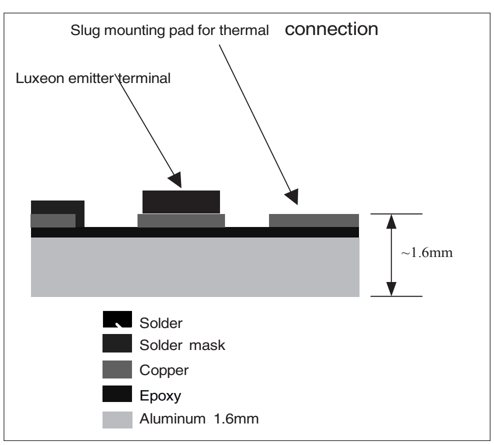

Figure 1. Cross Section of a Typical Metal (Al)-Core PCB at the Solder Pad Location.

Supply Chain and MCPCB Specification

A critical part of the design process of a LUXEON Power Light Source is the selection and fabrication of the MCPCB. This process can be divided into three stages with respective suppliers. The end product is a customer-ready MCPCB for LUXEON Emitter mounting.

Tier 1 Supplier

This is a base material supplier. Base material is the aluminum material with an insulating epoxy layer and a copper layer at the top of the stack.

Tier 2 Supplier

This is the MCPCB supplier. By etching the copper layer for the conduction paths between components, this supplier converts the base material into a PCB layout (see figure 7). A solder mask is added for protection of the copper layer once the etching is complete.

Tier 3 Supplier

This is a "board stuffer" who adds additional SMD components (such as resistors or connectors) to the MCPCB and prepares the LUXEON Emitter solder pads for a hot bar soldering process (see figure 8). The finished product is a MCPCB with solder wetted pads and mounted SMD components (resistors etc.) as required by system design.

Philips Lumileds uses the following specifications for procuring MCPCB's for standard LUXEON Power Light Sources:

Tier 1 Supplier Specification

· Aluminum thickness:	1.5mm
· Aluminum type:	5052
· Dielectric/Epoxy thickness:	100µm
· Dielectric/Epoxy material:	PREPREG
· Copper thickness:	35µm
· Thermal Conductivity:	1.0-1.8 W/mK

Tier 2 Supplier Specification

- Solder mask thickness: 6 - 16µm

Tier 3 Supplier Specification

- Solder paste thickness after reflow process - between 90 and 115µm (see figure 8a). For solder paste, Philips Lumileds utilizes OM325 with a composition of $Sn_{96.5}Ag_{3.0}Cu_{0.5}$.
- Often a single supplier can offer both tier 2 and tier 3 processes and can act as a purchasing agent for the tier 1 material.

Qualified Suppliers for Standard LUXEON Power Light Sources

Tier 1 Supplier
CCI - Paris, France

Tier 2 Supplier
Gainbase PCB Pte Ltd
10 Ubi Crescent, #07-12
Ubi Tech Park, Lobby B
Singapore 408564
Phone: 65-6749-8188
Fax: 65-6749-9088
http://www.gainbase.com

Tier 3 Supplier
Neways Advanced Electronics B.V.
Science Park Eindhoven 5010
5692 EA Son, The Netherlands
www.neways.nl

Notes on MCPCB Material Selection

1. MCPCB material with a thermal conductivity greater than 1.8 W/mK is not recommended as it will cause serious soldering problems.

2. Philips Lumileds recommends an epoxy resin as the insulating dielectric layer.

3. The choice of base material and suppliers must be determined by the customer and depends on the features desired of the final product.

MCPCB Design Guidelines

When designing a layout for a LUXEON MCPCB the following design guidelines are important:

- Follow the recommended layout for LUXEON Emitter solder pads as shown in figure 2.

- Create a heat barrier in between the solder pad and the electrical connection. Large areas of copper connected to the solder pad will draw heat away from the solder pad. This makes it more difficult to reach the required solder temperature and increases the time required to form the solder joint (see figure 3).

- Maximize the copper area beneath the slug. The copper layer will spread the heat over a larger area. This reduces the thermal resistance from slug to board (see figure 4).

- The copper pad areas for the LUXEON Emitter slug must be insulated from the solder pads and other slug pad areas, because the slug is not electrically isolated (see figure 5).

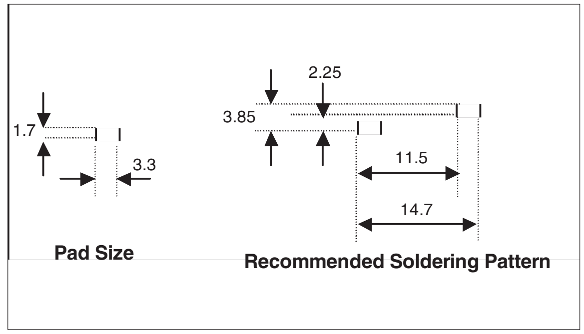

Figure 2. Solder Pad Layout

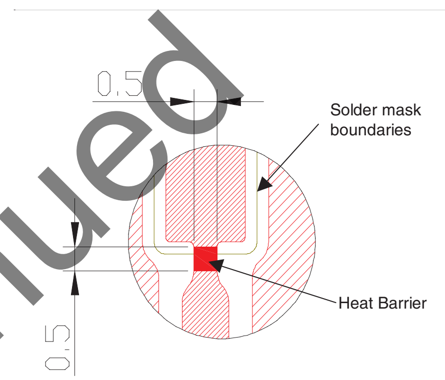

Figure 3. Creating a Heat Barrier for Hot-Bar Soldering.

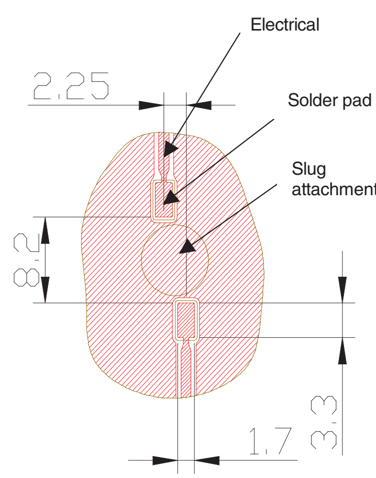

Figure 4. Maximizing Heat-Spreading Copper Layer Connected to Slug.

- Application of a solder mask layer protects the electrical traces during the hot bar soldering process (see figure 6).

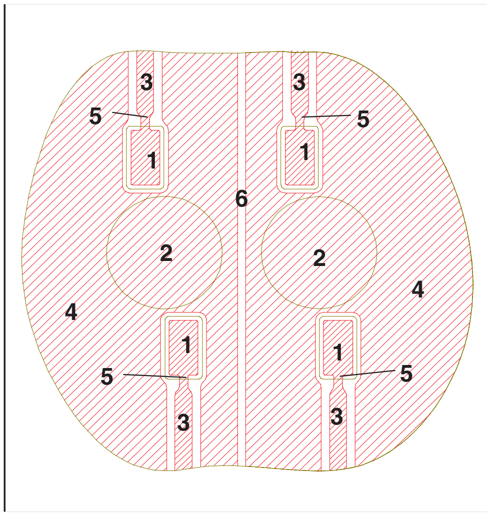

Figure 5: Assuring Electrical Insulation of the Slugs from Neighboring Emitters and Solder Pads.

Key for Figure 5:

1. Solder pad zones (solder mask free area inside black lines)
2. Slug pad zones (solder mask free area inside circles)
3. Trace electrical connection to solder pads
4. Heat spreading copper area, covered with solder mask for protection outside of slug attach zones
5. Heat barrier - reduced cross sectional area of copper from electrical traces to the solder pads
6. Electrical insulation between slug pad areas (no copper, epoxy covered with solder mask).

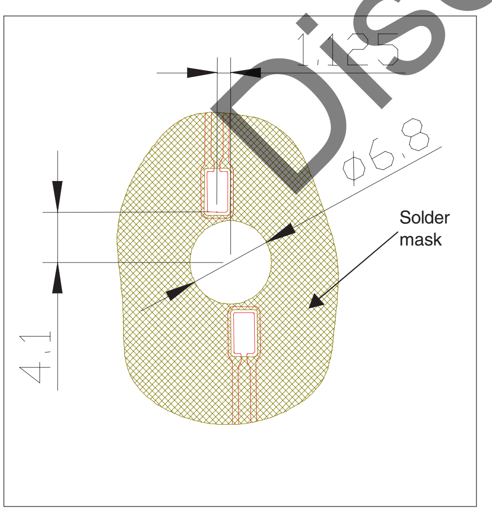

Figure 6: Solder Mask Protects Traces While Exposing Solder Pads and Slug Attach Areas for Array Assembly.

Process Flow to Build LUXEON Emitters into Power Light Sources

The following processes are followed in converting LUXEON Emitters into higher-level assemblies. These processes may be divided into three sub processes.

- Procurement and preparation of MCPCB (see figure 7)
- Solder pad preparation and SMD component mounting (see figures 8 and 8a)
- Mounting the LUXEON Emitter on the MCPCB (see figure 9)

Steps 1-4: Procurement and Preparation of MCPCB (see figure 7)

Steps 1-4 describe the fabrication of the MCPCB, which is similar to the standard FR4 PCB process. The layout is created and then copied via a photoresist and etching process. This process selectively etches through the copper layer, forming the electrical connections and heat spreading islands beneath the slugs in the remaining copper layer. A solder mask is added to protect the traces in the copper layer during the hot bar soldering process.

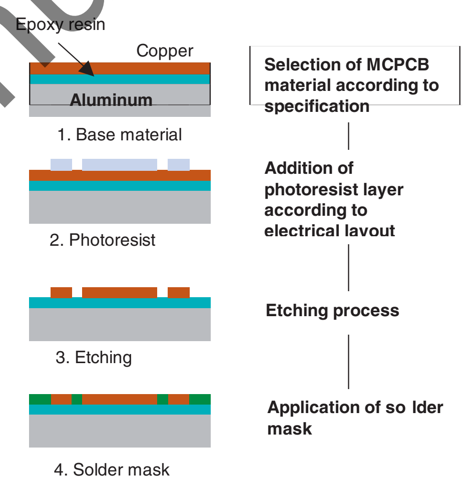

Figure 7. Steps 1-4, Procurement and Preparation of MCPCB.

Steps 5 and 6: Solder pad preparation and SMD component mounting (see figures 8 and 8a)

The second sub-process is the mounting of SMD components and the dispensing of solder paste on the solder pads. The next step involves reflow soldering the SMD components and plating tin on the solder pads. The height of the solidified tin should be between 90 and 115µm for optimal hot bar reflow soldering (see figure 8a). Philips Lumileds utilizes the following solder paste:

- OM325 - Alloy composition Sn96.5Ag3.0Cu0.5

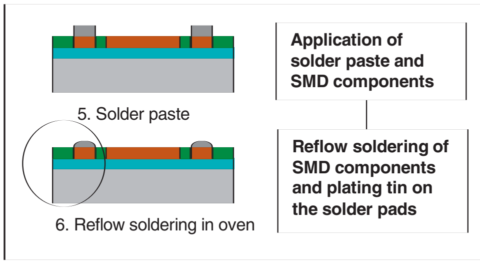

Figure 8. Steps 5 & 6, Solder Pad Preparation and SMD Component Mounting.

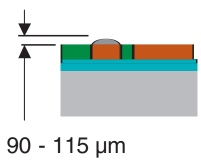

Figure 8a. Detail of Figure 8.

Steps 7-12: Mounting the LUXEON Emitter on the MCPCB (see figure 9)

Steps 7-12 are followed for mounting the LUXEON Emitters to the customer-ready MCPCB produced in steps 1-6.

Step 7: Application of Thermal Conductive Glue by Dispensing

The slug of LUXEON emitters must be glued to the MCPCB with thermally conductive adhesive to ensure a proper mechanical connection between MCPCB and the emitter while providing a proper thermal path for heat transfer.

A variety of thermally conductive glues are commercially available and Philips Lumileds strongly recommends that the user thoroughly evaluate an adhesive prior to use. At the time of writing Philips Lumileds was using Amicon E3503-01 for its LUXEON Power Light Sources.

Since the thermal resistance of the glue layer will affect the overall performance of the array it must be optimized. For optimal thermal connection it is important that the total slug area is wetted with adhesive after the emitter is placed on the MCPCB. The adhesive layer should be as thin as possible for good heat conductivity, but thick enough to ensure proper mechanical strength (typically 70µm). For further thermal design information, please consult Philips Lumileds Application Brief AB05, "Thermal Design Considerations for LUXEON Power Light Sources".

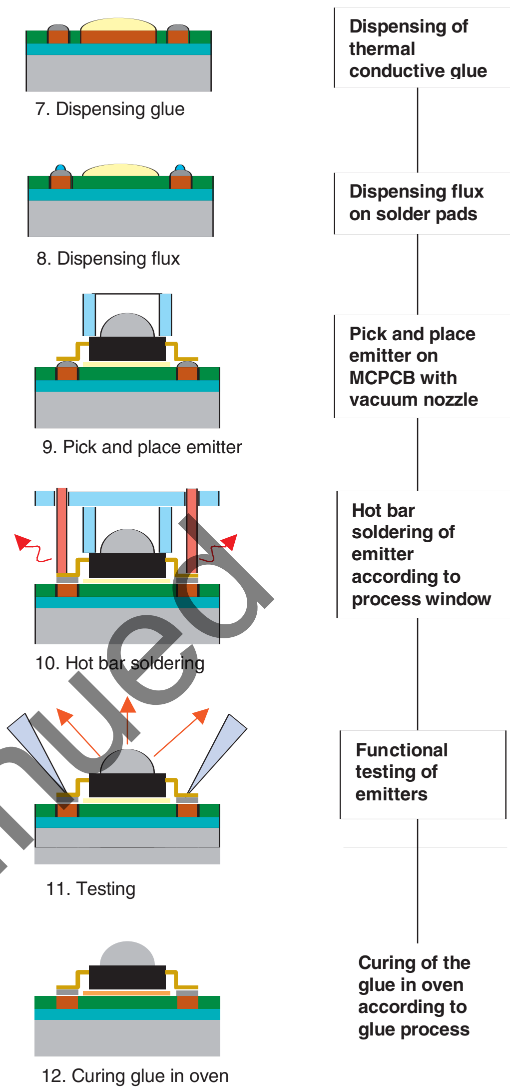

Figure 9. Steps 7-12, Mounting the LUXEON Emitter on the MCPCB.

Step 8: Application of Solder Flux by Dispensing

Solder flux is recommended for good heat transfer during the soldering of the emitter terminals to reduce the required soldering time. A selection of commercially available solder flux pastes include:

- α-Metals 390DH4
- α-Metals LR735
- α-Metals NS4029
- ESP 6-412
- Cobar 380SR-flux gel

The amount of flux should be optimized during the adjustment of the solder process. The right amount of flux will cause the solder to melt within about 0.4s.

NOTE: The spread of the flux compound should be restricted to the solder pad area.

Step 9: Placement of LUXEON Emitters

The best method of placing LUXEON Emitters is with automated pick-and-place equipment. It is recommended to follow these important guidelines:

- A 5N force for 100ms evenly spreads the glue over the entire area of the slug pad. Following these recommendations the resulting thickness of the glue layer is typically 70µm.
- LUXEON Emitters should be picked and placed by the housing (black body), not by the lens or the leads.
- The inner diameter of a vacuum pick-up nozzle should be greater than 6.1mm to avoid damage to the optical surfaces of the lens. See figure 12 for an example of a pick-and-place nozzle.

NOTE: Do not handle the LUXEON Emitter by the lens at any time during the assembly process. This can cause damage to the optical surfaces or may dislocate the lens if excessive force is applied.

Step 10: Soldering of Electrical Leads by Hot Bar Reflow Soldering

LUXEON Emitters have a maximum storage temperature of 120°C. Therefore it is not possible to use a reflow soldering process for array assembly. A hot bar soldering process is recommended when soldering LUXEON Emitters. This process will only transfer heat to the leads and avoids overheating the emitter that will damage the device.

The electrical leads of the LUXEON Emitter consist of 150µm ± 10µm copper alloy Olin 194 with the following plating:

- 70-130µ inches Nickel
- 3.0-9.0µ inches Palladium
- 0.5-3.0µ inches Gold

In order to transfer sufficient heat from the hot bar to the device, the following process parameters must be carefully considered:

- Amount of flux (see step 8)
- Pressing force of the solder tip
- Hot bar temperature

The recommended process window for temperature and force is shown in figure 10.

For the standard LUXEON Power Light Source assembly process, Philips Lumileds uses the following parameters:

- Hot Bar Temperature: 330°C
- Force of Hot Bar: 40 N
- Soldering time: 1.5 s

It is recommended to use a copper nickel-plated hot bar mounted to standard temperature controlled soldering equipment. See figure 13 for an example of a solder tip design.

A small amount of solder at the solder tip is necessary for a good heat transfer from the hot bars to the electrical leads. This can be obtained through proper design of the solder tip and by keeping the tip residue free.

A visual inspection may be used to check the quality of the solder joint (see figure 11).

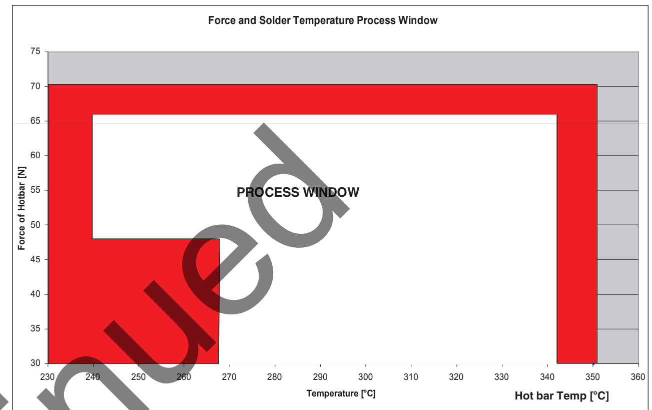

Figure 10. Hot Bar Soldering Recommended Process Window.

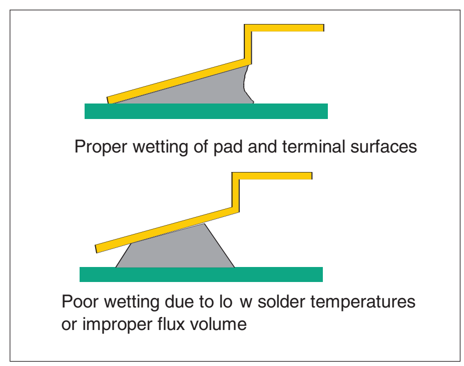

Figure 11. Solder Joint Inspection.

Step 11: Functional Testing of the Array

It is recommended to conduct optical and electrical testing of the finished assembly prior to curing the slug attach glue. Visual inspection verifies the electrical integrity of the assembly. If it is observed that the electrical connections are not intact or that the emitter has been damaged, rework can occur prior to curing the glue. Once the glue is cured it is difficult to remove the emitter without damage to the array.

For electrical testing the maximum emitter drive current must not be exceeded. Minimize the time of testing as at this process step the thermally conductive adhesive has not been cured.

Step 12: Glue Curing

Cured glue mechanically holds the emitter in place and forms a reliable thermal connection between the emitter and the MCPCB. Philips Lumileds recommends curing in a box oven with forced air. Follow the glue manufacturers curing instructions while respecting the LUXEON Emitter maximum storage temperature of 120°C.

Amicon E3503-01 requires a cure temperature of 100°C for 30 minutes.

Manual Hand Soldering

For prototype builds or small series production runs it is possible to place and solder the emitters by hand.

It is recommended to hand solder the leads with a solder tip temperature of 330°C for less than 1.5 seconds. This profile maintains a junction temperature below the maximum of 120°C, avoiding damage to the emitter or to the MCPCB epoxy layer. Damage to the epoxy layer can cause a short circuit in the array.

NOTE: Do not exceed the maximum junction temperature (120°C) during assembly, even for short durations.

Nozzle Design Example for Automated Pick-And-Place of LUXEON Emitters

Figure 12 shows an example of a pick-and-place nozzle for use with LUXEON Emitters. Use the following design rules for the nozzle design:

- Collar width greater than 6.1mm
- Collar inside height greater than 4.5mm

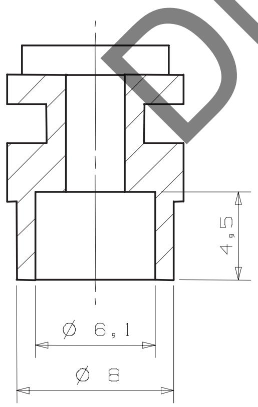

Figure 12. Pick and Place Nozzle Design.

Solder Tip Design Example for Automated LUXEON Array Assembly

Figure 13 shows an example of a Solder tip made from nickel-plated copper for use with LUXEON Emitters.

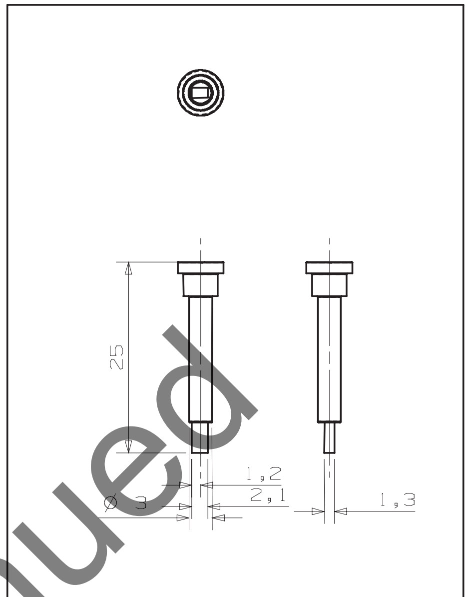

Figure 13. Solder Tip Design Example.

Company Information

LUXEON® is developed, manufactured and marketed by Philips Lumileds Lighting Company. Philips Lumileds is a world-class supplier of Light Emitting Diodes (LEDs) producing billions of LEDs annually. Philips Lumileds is a fully integrated supplier, producing core LED material in all three base colors (Red, Green, Blue) and White. Philips Lumileds has R&D centers in San Jose, California and in The Netherlands and production capabilities in San Jose and Penang, Malaysia. Founded in 1999, Philips Lumileds is the high-flux LED technology leader and is dedicated to bridging the gap between solid-state LED technology and the lighting world. Philips Lumileds technology, LEDs and systems are enabling new applications and markets in the lighting world.

Philips Lumileds may make process or materials changes affecting the performance or other characteristics of our products. These products supplied after such changes will continue to meet published specifications, but may not be identical to products supplied as samples or under prior orders.

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