

# LUXEON 3535L, LUXEON 3535 2D and LUXEON 3535 HV



## Assembly and Handling Information

### Introduction

This application brief addresses the recommended assembly and handling guidelines for LUXEON 3535L, LUXEON 3535 2D and LUXEON 3535 HV emitters. These emitters deliver high efficacy and quality of light for distributed light source applications in a compact 3.5mm x 3.5mm package. Proper assembly, handling, and thermal management, as outlined in this application brief, ensure high optical output and reliability of these emitters.

### Scope

The assembly and handling guidelines in this application brief apply to the following LUXEON product(s):

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LUXEON 3535L

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LUXEON 3535 2D

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LUXEON 3535 HV

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In the remainder of this document the term LUXEON emitter refers to any product in the LUXEON series listed above.

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# 1. Component

## 1.1 Description

The LUXEON 3535L, LUXEON 3535 2D and LUXEON 3535 HV emitters (Figure 1) consist of a 3535 lead-frame package with an anode and a cathode. A small notch on the corner of the package marks the cathode side of the emitter package. The anode and cathode both serve as thermal pads for the emitter, with the majority of the heat being dissipated through the larger pad, corresponding to the cathode. The LUXEON emitter does not include any transient voltage suppressor (TVS) chip to protect the emitter against electrostatic discharges (ESD). Appropriate precautions should therefore be taken when handling this device (see Section 5.5).

## 1.2 Optical Center

The optical center coincides with the mechanical center of the LUXEON emitter. Optical rayset data for the LUXEON emitter are available on the Philips Lumileds website at [www.philipslumileds.com](http://www.philipslumileds.com).

## 1.3 Handling Precautions

The LUXEON emitter is designed to maximize light output and reliability. However, improper handling of the device may damage the silicone coating and affect the overall performance and reliability. In order to minimize the risk of damage to the silicone coating during handling, the LUXEON emitter should only be picked up from the side of the package.

## 1.4 Cleaning

The LUXEON emitter should not be exposed to dust and debris. Excessive dust and debris may cause a drastic decrease in optical output. In the event that a LUXEON emitter requires cleaning, first try a gentle swabbing using a lint-free swab. If needed, a lint-free swab and isopropyl alcohol (IPA) can be used to gently remove dirt from the silicone coating. Do not use other solvents as they may adversely react with the package of the LUXEON emitter. For more information regarding chemical compatibility, see Section 6.

## 1.5 Electrical Isolation

The LUXEON emitter has two electrodes, with a nominal spacing of 0.65mm, at the bottom of the package. In addition, the LUXEON emitter contains two tabs on the side of the package. These tabs are cut-off remnants of the lead-frame and are electrically connected to the anode and cathode, respectively. So it is important to keep sufficient distance between the LUXEON emitter package and any other objects or neighboring LUXEON emitters to prevent any accidental shorts.

In order to avoid any electrical shocks and/or damage to the LUXEON emitter, each design needs to comply with the appropriate standards of safety and isolation distances, known as clearance and creepage distances, respectively (e.g. IEC60950, clause 2.10.4).

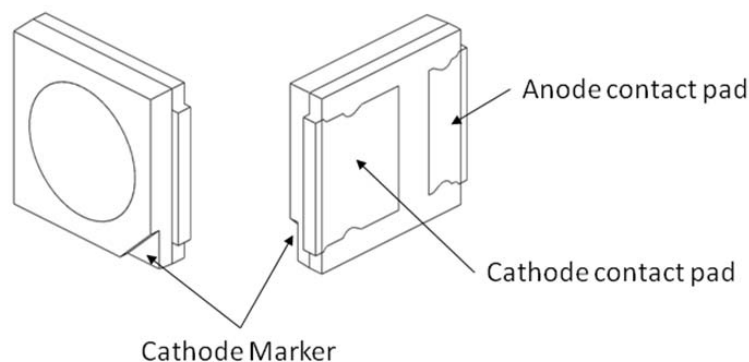


Figure 1. Package rendering of the LUXEON 3535L, LUXEON 3535 2D and LUXEON 3535 HV emitters.

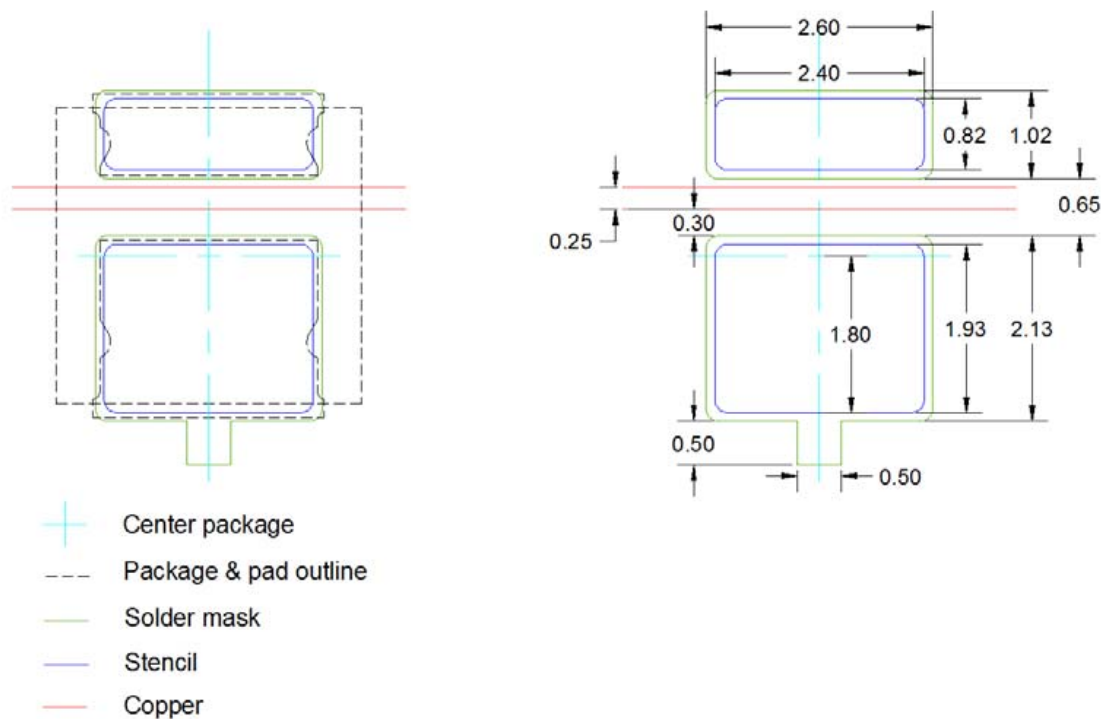


Figure 2. Recommended PCB footprint design for the LUXEON emitter. In order to ensure proper heat dissipation from the package electrodes to the PCB, it is best to extend the top copper layer of the PCB several millimeters beyond the package of the LUXEON emitter. All dimensions are in mm.

## 1.6 Mechanical Files

Mechanical drawings for the LUXEON emitter are available on the Philips Lumileds website at [www.philipslumileds.com](http://www.philipslumileds.com).

## 2. PCB Design Guidelines for the LUXEON Emitter

The LUXEON emitter is designed to be soldered onto a Printed Circuit Board (PCB). To ensure optimal operation, the PCB should be designed to minimize the overall thermal resistance between the LED package and the heat sink.

### 2.1 PCB Footprint and Land Pattern

The recommended PCB footprint design for the LUXEON emitter is shown in Figure 2. In order to ensure proper heat dissipation from the emitter electrodes to the PCB, it is best to extend the top copper layer of the PCB beyond the perimeter of the LUXEON emitter by 3mm – 4mm (see Section 3).

### 2.2 Surface Finishing

Philips Lumileds recommends using a high temperature organic solderability preservative (OSP) or electroless nickel immersion gold (ENIG) plating on the exposed copper pads.

### 2.3 Minimum Spacing

Philips Lumileds recommends a minimum edge to edge spacing between LUXEON emitters of 0.5mm. Placing multiple LUXEON emitters too close to each other may adversely impact the ability of the PCB to dissipate the heat from the emitters and may cause accidental shorts between the metal stubs on the side of neighboring LUXEON emitters.

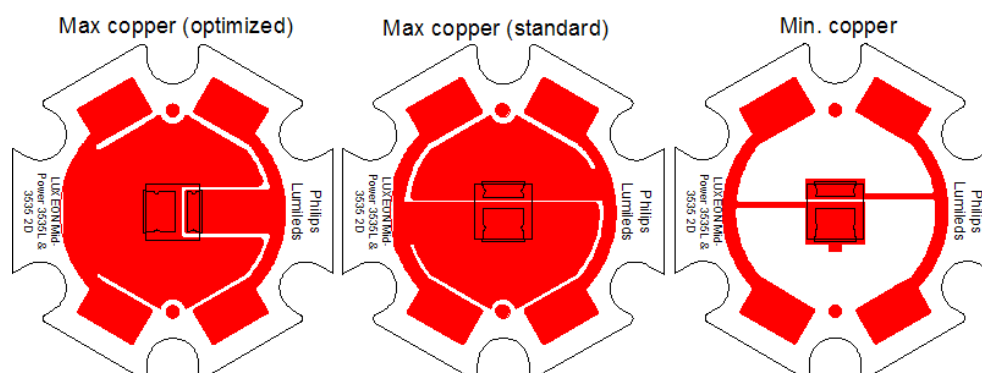


Figure 3. Top copper trace patterns showing the maximum (optimized and standard) and minimum top side metallization. For the maximum copper design, one can optimize the copper trace pattern to take into account that the heat is mainly dissipated from the cathode pad. There is no need to have large copper area around the anode.

### 3. Thermal Management

The overall thermal resistance between a LUXEON emitter and the heat sink is strongly affected by the design and material of the PCB on which the emitter is soldered. Metal Core PCBs have been historically used in the LED industry for their low thermal resistance and rigidity. However, MCPCBs may not always offer the most economical solution. Multi-layer epoxy FR4 PCBs are commonly used in the electronics industry and can, if properly designed, yield an appropriate low-cost solution for various LED applications.

Philips Lumileds investigated the thermal performance of LUXEON emitters on a 1.0mm thick FR4 PCB with a top copper plating of 35µm. In order to quantify the impact of the PCB metallization on the overall thermal resistance between junction and heatsink, two different top side metallization configurations were evaluated (see Figure 3). Maximum copper standard and minimum copper top trace pattern corresponding to copper pads which did not extend beyond the outline of the LUXEON emitter package. The latter configuration is representative of the worst case condition for applications where multiple LEDs are placed in close proximity to each other. Maximum top size metallization corresponds to copper pads which extend several millimeters beyond the outline of the LUXEON emitter package. This situation is representative for distributed light applications where multiple LEDs are placed relatively far apart. Similar experiments with FR4 PCBs, which had full metallization at the bottom as well (double sided copper clad PCB), did not yield any noticeable improvement in PCB thermal resistance performance.

Table 1. Typical junction-to- $T_s$  thermal resistance values for FR4 PCBs with minimum and maximum (standard) top side metallization.

DEVICE	TOP SIDE METALLIZATION PATTERN	TYPICAL $R\theta_{j-s}$ [K/W]
LUXEON 3535L	Max copper (standard)	32
LUXEON 3535L	Min copper	28
LUXEON 3535 2D	Max copper (standard)	32
LUXEON 3535 2D	Min copper	28
LUXEON 3535 HV 24V	Max copper (standard)	33
LUXEON 3535 HV 48V	Max copper (standard)	14

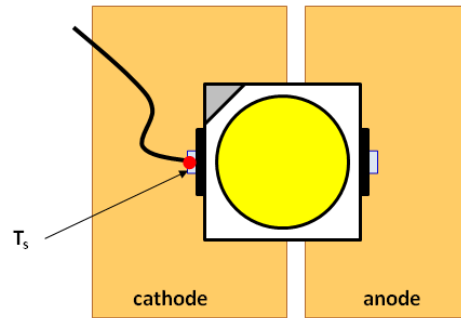


Figure 4. The recommended temperature measurement point  $T_s$  is located right next to the cathode of the LUXEON emitter on the PCB.

## 4. Thermal Measurement Guidelines

The typical thermal resistance  $R\theta_{j-case}$  between the junction and the solder pads of the LUXEON emitter is provided in the datasheet. With this information, the junction temperature  $T_j$  can be determined according to the following equation:

$$T_j = T_{case} + R\theta_{j-case} \cdot P_{electrical}$$

In this equation  $T_{case}$  is the temperature at the bottom of the solder pads of the LUXEON emitter and  $P_{electrical}$  is the electrical power going into the emitter. In typical applications it may be difficult, though, to measure the temperature  $T_{case}$  directly. Therefore, a practical way to determine the junction temperature of the LUXEON emitter is by measuring the temperature  $T_s$  of a predetermined sensor pad on the PCB with a thermocouple. The recommended location of the sensor pad is right next to the cathode of the LUXEON emitter on the PCB, as shown in Figure 4. To ensure accurate readings, the thermocouple must make direct contact with the copper of the PCB onto which the LUXEON emitter pads are soldered, i.e. any solder mask or other masking layer must be first removed before mounting the thermocouple onto the PCB. The thermal resistance  $R\theta_{j-s}$  between the sensor pad and the LUXEON emitter junction was experimentally determined on FR4 PCBs with minimum and maximum metallization (see Table 2). The junction temperature can then be calculated as follows:

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

Table 2. Typical junction-to- $T_s$  thermal resistance values for FR4 PCBs with minimum and maximum (standard) top side metallization.

TOP SIDE METALLIZATION	TYPICAL $R\theta_{j-BOTTOM\ PCB}$ [K/W]	TYPICAL $R\theta_{j-s}$ [K/W]
Minimum	100	28
Maximum	58	32

## 5. Assembly Process Guidelines

### 5.1 Stencil Design

The recommended solder stencil thickness is 125µm.

### 5.2 Solder Paste

Philips Lumileds recommends lead-free solder for the LUXEON emitter. Philips Lumileds tested SAC 305 solder paste from Alpha Metals (OM338 grade 3 and OM 325 grade 4) with satisfactory results. However, since application environments vary widely, Philips Lumileds recommends that customers perform their own solder paste evaluation in order to ensure it is suitable for the targeted application.

## 5.3 Solder Reflow Profile

The LUXEON emitter 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 maintained.

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.

## 5.4 Pick and Place

The LUXEON emitter is packaged and shipped in tape-and-reel which is compatible with standard automated pick-and-place equipment to ensure the best placement accuracy. Note that pick and place nozzles are customer specific and are typically machined to fit specific pick and place tools.

## 5.5 Electrostatic Discharge Protection

The LUXEON emitter does not include any transient voltage suppressor (TVS) chip to protect against electrostatic discharges (ESD). Therefore, Philips Lumileds recommends observing the following precautions when handling the LUXEON emitter:

- During manual handling always use a conductive wrist band or ankle straps when positioned on a grounded conductive mat.
- All equipment, machinery, work tables, and storage racks that may get in contact with the LUXEON emitter should be properly grounded.
- Use an ion blower to neutralize the static discharge that may build up on the surface and lens of the plastic housing of the LUXEON emitter during storage and handling.

LUXEON emitters which are 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. To determine whether any device is damaged by ESD, measure the light output and forward voltage of the emitter which is suspect. A forward voltage above 2.0V for a drive current of 0.1mA typically indicates that the LED is not damaged.

# 6. LUXEON Emitter Drivers

## 6.1 Introduction

LED is best driven with current source. This mode of operation provides the best control of the amount of current flowing through the LEDs at any operating temperature. A voltage source does not provide a predetermined current, may vary significantly and depends on the forward voltage and the operating temperature of the LEDs. However a voltage source can be assembled with few passive components such resistor, capacitor and bridge rectifier, assuming incoming AC power supply. Such configuration is cheap and compact but has poor power efficiency and poor current control. This section discusses LED current drivers via active controls (more common) incorporating transistors and linear ICs such as constant current regulators (CCRs).

## 6.2 Active Control LED Current Driver

There are two types of active control LED current drivers:

Linear regulated power supply

Switch mode power supply

The main difference is how the power supply is being regulated. In linear regulated power supply, the transistor connected to a load is used to control the output voltage or current. In order to do this, the transistor must operate in the ohmic or linear region as shown in Figure 5. Since there is current flowing through the transistor (operating in ohmic region), the transistor behaves like a variable resistor and generates heat.

In a switched mode power supply, as the name implies, the transistor is used as a switch to either switch in or out electrical storage elements such as inductor (current source) or capacitor (voltage source) to a load. In order to achieve this, the transistor must be operating in the saturation region as shown in Figure 5. In the "ON" or close switch, there is hardly any resistance through the transistor and hence does not generate any heat when a current flows through it. In "OFF" or open switch, no current is flowing through the transistor. This type of power supply has high power efficiency than the linear regulated power supply. However due to the switching of the circuit, it generates electromagnetic interference (EMI) which must be taken into account and minimized during the design stage. There are several switch mode power supply configurations such as buck, boost and buck-boost convertor.

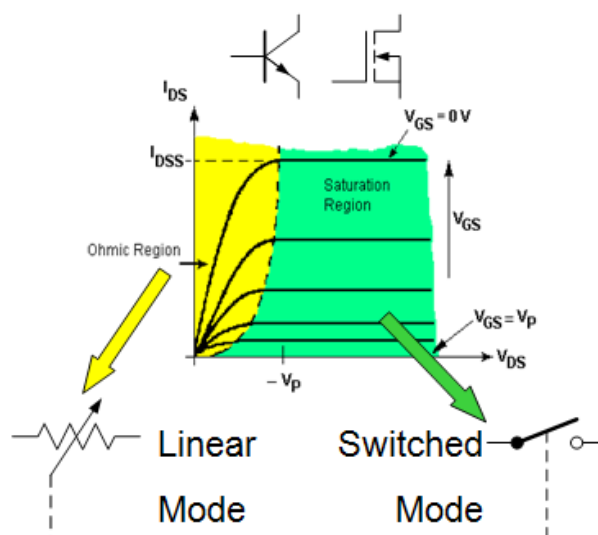


Figure 5. Typical transistor operation regions. Ohmic or linear region is shaded in yellow while the saturation or switching region is shaded green.

A summary of the major differences between these two active control LED current drivers is given in Table 3 below.

Table 3. Comparison of a typical linear regulated versus switch mode power supply.

	LINEAR	SWITCH MODE
Cost	Cheap	Expensive
EMC	None	Potential
Circuitry	Simple	Complicated
Power Efficiency	Low (~50...~70%)	High (~75%...~95%)
Size & Weight	Big and heavy*	Small and light

\*: if magnetics are used to step down the voltage before the regulator.



A typical example of an AC-DC LED system block circuit may consist of a bridge rectifier, transient circuit protection (e.g. varistor), dimming circuit (triac) and a control circuit (either passive or active control) with flicker-free, over-voltage protection, filters and/or feedback loop circuits. Figure 6 shows an example of a system block diagram of a typical LED driver circuit. Philips Lumileds maintain a list of various linear IC driver manufacturers. Examples of various driver circuit designs are provided by each manufacturer. To access this information, go to Philips Lumileds website at [www.philipslumileds.com](http://www.philipslumileds.com). Move the mouse pointer to the “Support” tab and select “Design Tools”. On the left menu of the “Philips Lumileds Tools” window, click on the “Eco-system” and then the “Drivers” tab.

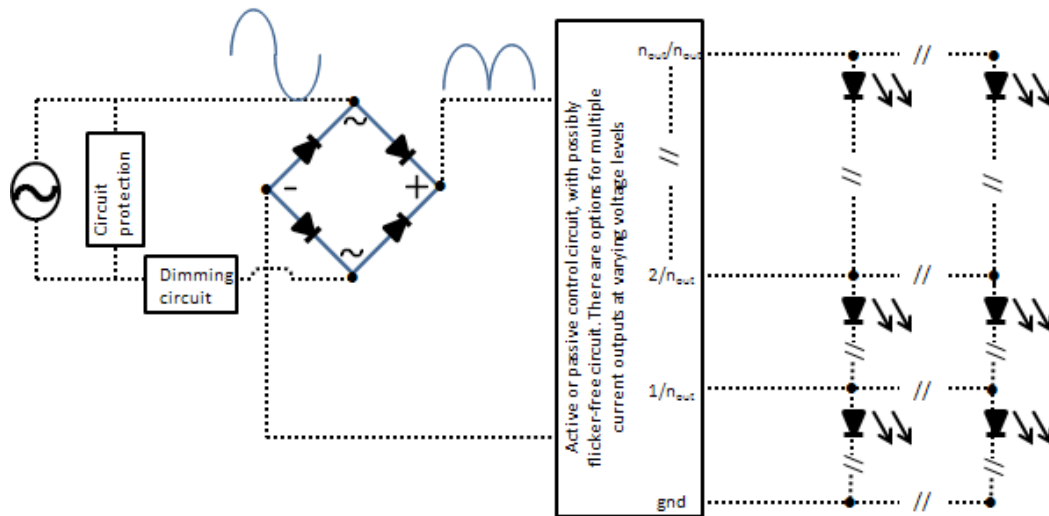


Figure 6. A typical system block diagram of one example of a LED driver circuit.

## 7. Packaging Considerations – Chemical Compatibility

The LUXEON emitter package contains a silicone overcoat to protect the LED chip 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 used in the LUXEON emitter 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 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, VOCs captured inside the silicone may partially oxidize and create a 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 4 provides a list of commonly used chemicals that should be avoided as they may react with the silicone material. Note that Philips 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 4 are typically not directly used in the final products that are built around LUXEON emitters. 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. Philips 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 4. List of commonly used chemicals that will damage the silicone of the LUXEON emitter.**  
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
tetrachlorometane	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

Lumileds is the light engine leader, delivering innovation, quality, and reliability.

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.

To learn more about our portfolio of light engines visit [www.lumileds.com](http://www.lumileds.com).



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