Handling and Processing Details for Ceramic LEDs
Application Note

Abstract

This application note provides information about the recommended handling and processing of ceramic LEDs from OSRAM Opto Semiconductors. Beside a fundamental overview of the various types of LEDs and their construction, diverse details especially regarding the handling and processing of the LEDs are presented.

Overview of ceramic LEDs

In addition to standard LEDs with a plastic package, OSRAM Opto Semiconductors also has LEDs in its portfolio which are mounted on a ceramic substrate or with a ceramic package for a multitude of applications (Figure 1). With respect to their basic construction the ceramic LEDs can be subdivided into various groups or categories.

- LEDs with a sintered ceramic package
- LEDs with a ceramic substrate and silicon encapsulant
- LEDs with a ceramic substrate and a glass cover

LEDs with a sintered ceramic package

In this case, the package consists of a ceramic box whose side walls are either straight or formed as a reflector, depending on the type. After the assembly and contacting of one or more semiconductor chips, the ceramic package is then cast with a clear or diffuse silicon encapsulant. The electrical contacts are located on the side or underside of the package. This package category includes the various LEDs of the product families CERAMOS, CERAMOS REFLECTOR and Multi CERAMOS.

LEDs with ceramic substrate and silicone

The construction of LEDs in this group consists of a ceramic substrate on which the chips are attached and contacted. The rest of the package consists of a hard silicon encapsulant, which, depending on the respective type, is formed as a lens. In this case, the electrical contacts are generally located underneath the ceramic substrate. This group contains the LED types CERAMOS Flash and OSLON.

Figure 1: Overview of the different packages of the ceramic LEDs from OSRAM Opto Semiconductors
LEDs with a ceramic substrate and glass

In this case as well, the base of the LED is a ceramic substrate on which the chips are attached and contacted. In this group, however, the cover of the chips and the wire bonding occurs by means of an attached glass element. This basically provides protection against physical contact, and does not hermetically seal the component from the environment. Depending on the product family, the electrical contact occurs by means of side contacts as is the case with the OSTAR SMT, or bottom-only terminations, as is the case with the OSTAR Compact.

Handling

In addition to general guidelines for the handling of LEDs, additional care should be taken that mechanical stress on the ceramic package or substrate and particularly, stresses (e.g. sheering forces) to the glass cover or the lens are avoided. This means, for example, that the relevant LED must not be picked up or handled by the glass or the lens.

![Figure 2: Incorrect handling at the lens or at the silicone](image)

By means of individually exchangeable soft rubber suction tips, the effective mechanical stress on the LED is minimized. The vacuum stylus functions such that by pressing on the button, a vacuum is created, with which the component (e.g. the LED) can be lifted. By releasing the pressure on the button, the vacuum is removed and the component can be placed at the desired position.

If there is not an alternative to the use of forceps, the LED must be picked and handled only at the ceramic substrate (Figure 4).

When placing the LED into operation, it should be guaranteed that especially the high power OSTAR types are provided with sufficient cooling. Depending on the given circumstances, extended operation without heat dissipation can lead to overheating, damage or failure of the component.

For manual assembly and placement – in the production of prototypes, for example – the use of so-called vacuum tweezers is recommended (Figure 3).
When processing by means of automated placement machines, care should generally be taken that an appropriate pick and place tool is used and that the process parameters conform to the package characteristics.

Figure 5 shows an overview of the recommended designs of the placement tools for damage-free processing of the individual ceramic LEDs.

Cleaning

In general, OSRAM Opto Semiconductors does not recommend a wet cleaning process for components like the OSTAR SMT and OSTAR Compact as the package is not hermetically sealed. Due to the open design, all kind of cleaning liquids can infiltrate the package and cause a degradation or a complete failure of the LED. It is also recommended to prevent penetration of organic substances from the environment which could interact with the hot surfaces of the operating chips.

Ultrasonic cleaning is generally not recommended for all types of LEDs (see also the application note "Cleaning of LEDs"). As is standard for the electronic industry, OSRAM Opto Semiconductors recommends using low-residue or no-clean solder paste, so that PCB cleaning after soldering is no longer required.

In any case, all materials and methods should be tested beforehand in order to determine whether the component will be damaged in the process.

Detailed information can also be found in the individual data sheet of each LED.
Storage

PCBs or assemblies containing LEDs should not be stacked such that force is applied to the LED, or should not be handled directly at the LED.

Figure 6: Incorrect storage of LEDs

Generally, all LED assemblies should be allowed to return to room temperature after soldering, before subsequent handling, or the next process step.

Processing (Mounting and Soldering)

Generally, all ceramic LEDs are compatible with existing industrial SMT processing methods, so that all current populating techniques can be used for the mounting process.

The individual soldering conditions for each LED type according to JEDEC can be found in the respective data sheet.

A standard reflow soldering process with convection air or N₂ is recommended for mounting the component, in which a typical lead-free SnAgCu metal alloy is used as solder. Figure 7 shows the temperature profile for lead-free soldering with the recommended peak temperature of 245°C.

In this context, it is recommended to check the profile on all new PCB materials and designs. As a good starting point, the recommended temperature profile provided by the solder paste manufacturer can be used. The maximum temperature for the profile as specified in the data sheet should not be exceeded, however.

For ideal mounting of the various ceramic LED-types to the circuit board, some aspects of the soldering process should be taken into consideration.

Figure 7: Temperature profile for lead-free reflow soldering according to JEDEC JSTD-020
Selection of PCB type
Design of the solder pad
Design of the solder stencil

When developing the circuitry, special attention should be given to the position and orientation of the LED on the circuit board. Depending on the position and orientation of the LED, the mechanical stress on the LED can vary.

In general, it is recommended that all twisting, warping, bending and other forms of stress to the circuit board should be avoided after soldering in order to prevent breakage of the LED housing or solder joints. Therefore, separation of the circuit boards should not be done by hand, but should exclusively be carried out with a specially designed tool.

PCB Type

In addition to their primary function as a mechanical substrate and electrical contacting element for the components, modern circuit boards also have the task of ensuring stable characteristics within the circuitry, and especially for high-power devices, to efficiently dissipate the heat which arises.

The selection of appropriate materials for the circuit board is therefore of utmost importance, since the total thermal resistance of the system should be kept as low as possible. Materials or composites with insufficient thermal conductivity lead to an impairment of reliability or restrict operation at optimal performance, since the heat which arises cannot be dissipated in sufficient quantities.

Depending on the total input power, the application conditions and requirements, ceramic based LEDs can be mounted on various PCB materials, such as:

- Flex PCB (FCP)
- FR4 / FR4 with thermal vias
- Flex on aluminum/copper
- Metal core PCB (IMS-PCB)
- PCB with exposed copper
- Ceramic

In general, FR4 with plated through holes (PTH = thermal vias) provides significant advantages compared to a pure FR4 material, since the thermal resistance of the material is significantly improved with the implementation of vias.

For applications, this has the positive effect that in spite of higher thermal loading, an expensive metal core PCB can be eliminated, since the heat which arises can be efficiently dissipated.

The thermal transfer capability of the vias themselves is determined by the thickness of the copper in the through holes. In the industry standard thicknesses of 20-25µm copper are established whereas also higher lamination strengths are used. In this case, it can generally be said that the thicker the copper layer, the better the performance, but also at a higher cost.

Nevertheless, when using a composite consisting of a thin double-sided FR4 material (0.4≤d<1.0 mm) with thermal vias and an additional cooling, it should be kept in mind that a good thermal coupling between the FR4 material and the heat sink is guaranteed by means of a thermal interface material.

When using an IMS-PCB, it should be considered that the difference in the coefficients of thermal expansion (CTE) between the ceramic material of the LED and the IMS PCB creates stress on the solder joint.

To minimize the effect, copper (Cu) is therefore preferred over aluminum (Al) as base plate material because of the lower CTE.

For example, an IMS-PCB with 150 µm dielectric and 1.5 mm copper base was tested in combination with LEDs of the OSTAR groups.
With respect to the dissipation and distribution of heat, the PCB with exposed copper shows promises the best results, but is also associated with higher costs. With this type of PCB, the thermal pad of the LED is directly soldered on to the exposed base plate so that the heat can be dissipated without requiring any insulation between the thermal pad, the metal layer and the heat sink. This permits the LEDs of the OSTAR to be operated at higher currents or higher power levels, for example.

In summary, the design, construction and material of the PCB are essential for an optimized thermal design. As a consequence, it is therefore recommended to appropriately verify the entire system, in order to improve the operational characteristics of the LED.

**Solder Pad**

Since the solder pad effectively creates the direct contact between the LED and the circuit board, the design of the solder pad decisively contributes to the performance of the solder connection. The design has an influence on the solder joint reliability, the self-centering effect and heat dissipation, for example.

In most cases, it is therefore advantageous to use the recommended solder pad, since it is individually adapted to the properties and conditions of the LED. The corresponding solder pad can be found in the data sheet of each LED. Based on the given designs an optimized balance between good processability, the smallest possible positioning tolerance and a reliable solder connection can be achieved.
However it should be noted that the self-centering effect is limited in its extent. Slightly misaligned components (less than 0.150 mm) will be automatically aligned during reflow due to the self-centering effect of the symmetrical pad design (Figure 9).

If the placement position is greater than 150 µm from the center, the components should not be refloved as electrical shorts resulting from solder bridges may be produced.

**Figure 9: Self alignment during reflow soldering (e.g. OSLON, OSTAR SMT and OSTAR Compact)**

Since the placement and rotational alignment of the component depends on the process and the equipment, an optimization must take both factors into consideration.

In general, the requirements for good thermal management should be taken into consideration in the application when designing the solder pads. In the end, this means that when designing the solder pads, the copper area should be kept as large as possible. This serves to dissipate and spread the generated heat over the PCB and is typically covered with a layer of solder resist.

**Solder stencil**

In the SMT process, the solder paste is normally applied by stencil printing. The amount to be applied as well as the quality of the paste deposits and the entire printing are primarily influenced and determined by the design of the printing stencil. In the end, this also has an influence on the solder quality, since effects such as solder bridges, solder spray and/or other soldering defects are largely determined by the design of the stencil apertures and the quality of the stencil printing (e.g. positioning, cleanliness of the stencil, etc.).

The stencils and their apertures are thus specially laid out for the respective application.

As an example, the recommended design and dimensions of the stencil apertures for the solder pad for the OSLON are shown in Figure 10.

**Figure 10: Solder stencil for LEDs of the OSLON product family**
Ideally, the apertures should be rounded rather than square. This prevents solder from accumulating in the corners (less adhesion) which finally leads to smearing during printing.

Furthermore, the stencil apertures are typically smaller than the recommended solder pad. This helps to minimize the formation of solder bridges.

When printing with a stencil, the amount of solder paste is determined by the thickness of the stencil.

For all ceramic LEDs, a thickness of 120 µm is suitable. However, the stencil thickness used may also depend on the other SMD components on the PCB.

If needed, an appropriate solder stencil design can be found in the data sheet for the LED.

**Voids**

For a good thermal connection and a high board level reliability, it is recommended that voids and bubbles should be eliminated in all solder joints.

A total elimination of voids, particularly for the larger thermal pad, is difficult. Therefore, the design of the stencil aperture is crucial for minimization of voids.

The recommended design with smaller multiple openings in the stencil enables an out-gassing of the solder paste during the reflow soldering process and also serves to regulate the final solder thickness. Therefore, a typical solder paste coverage of 50%-70% is recommended.

In industry standards like IPC-A-610 D or J-STD-001D (which refer only to surface mount area array components like BGA, CSP, etc.) the amount of voids (verified by the x-ray pattern) should be less than 25%.

**Figure 11: X-ray image of a solder joint (e.g. OSTAR SMT)**

Internal studies and simulations at OSRAM Opto Semiconductors have determined, however, that for areas up to 50% of the thermal pad area, the voids only have a minor effect on the thermal resistance. The limit of the acceptable voiding can vary for each application and depends on the power dissipation and the total thermal performance of the system, affected by the PCB materials used.

**Solder Joint/Post reflow inspection**

Other than the OSTAR SMT and the Multi CERAMOS, all ceramic LEDs fall into the category of "bottom-only terminated" SMT components in IPC-A-610-D, solder joint inspections of these LEDs are typically accomplished with transmission type x-ray equipment (similar to QFN packages).

X-ray inspection system can detect bridges, shorts, opens, and solder voids. In the industry, x-ray inspection is typically used to define process settings and parameters and is then used to monitor the production process and equipment for process control and is not performed as a 100-percent inspection.

To support the visual inspection of the solder wetting after reflow soldering, a so called "solder wetting indicator" can be designed into the solder pad.
In contrast, the electrical contacts of the OSTAR SMT and Multi CERAMOS are formed to castellated terminations determined by the geometry. Because of this, a visual inspection of the solder joints should be carried out according to the IPC standard J-STD-001D 7.6.6. Figure 13 shows an example and the scheme of a well formed solder joint at the electrical terminal of the OSTAR – SMT.

As the scheme shows, the maximum solder fillet height is defined as the sum of the solder stand off and one half of the ceramic substrate thickness \(E=G+\frac{1}{2}H\), due to the special geometry and the different surface plating of the castellated terminations.

**Verification of the design**

Despite the opportunities offered by thermal simulation it is recommended that the design and/or the thermal management should be verified with a prototype under real conditions including all additional heat sources.

Here, the solder point temperature \(T_S\) of the LED is taken as a basis for calculating the junction temperature \(T_J\). The solder point temperature itself refers to the back of the device, where the thermal resistance of the LED is also defined.

Since ceramic LEDs are usually mounted on a circuit board, it is often difficult or impossible to measure the solder point temperature directly on the underside of the device.

The simplest and most practicable solution for enclosed applications is a temperature measurement via a thermocouple on the surface of the PCB.

The thermocouple must be fixed directly alongside the ceramic material. In doing so, a temperature difference between the solder pad temperature and the measurement point must be taken into consideration when calculating the junction temperature. The extent of the difference therefore depends on various parameters, e.g. setup, PCB material, operating conditions, etc.

**Summary**

With their compatibility to customary processing techniques, ceramic LEDs place no special requirements with respect to processing.

In general, it should be noted, however, that the housing or the base substrate of the
ceramic LEDs is made of ceramic and therefore is significantly more brittle than plastic housings.

As shown in the application note, in order to ensure a good thermal connection and high reliability of the solder joints in an application which makes use of ceramic LEDs, the PCB design and PCB material must be carefully selected and specified.

In general, the design, construction and material of the PCB are essential for an optimized thermal design. As a consequence, therefore, it is recommended to appropriately verify the entire system, in order to improve the operational characteristics of the LED.

OSRAM Opto Semiconductors supports its customers during their development and design process in finding the best solution for a specific application.

Appendix

Appendix

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

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About Osram Opto Semiconductors
Osram Opto Semiconductors GmbH, Regensburg, is a wholly owned subsidiary of Osram GmbH, one of the world’s three largest lamp manufacturers, and offers its customers a range of solutions based on semiconductor technology for lighting, sensor and visualisation applications. The company operates facilities in Regensburg (Germany), San José (USA) and Penang (Malaysia). Further information is available at www.osram-os.com.

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