Details of the Assembly and Solder Pad Design of the OSLON, OSLON SSL and OSLON Square Family

Application Note

Abstract

This application note gives general information on the assembly and design of the solder pad of the OSLON, OSLON SSL and OSLON Square family. Suitable PCB materials will also be described. At the end some details regarding the second board reliability are given.

OSLON LEDs

The OSLON LED was developed particularly for applications that need maximum luminous flux with little consumption of space, and on which very stringent requirements regarding lifetime are imposed. With their performance and design they are suitable for various forms of lighting and illumination technology, ranging from general lighting, industry, backlighting, projection to automotive applications.
Due to their very compact design, the LEDs are also particularly suitable for being combined and operated in clusters.

The design of the OSLON group is based on a collective package concept comprising a ceramic base with integrated contacts (bottom only-terminated) and a hard silicone cast as a lens (Fig. 2).

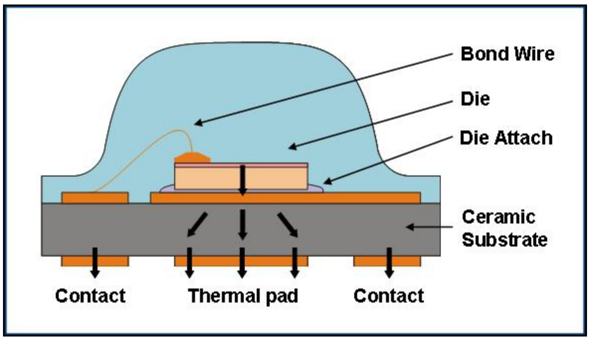


Fig. 2: Principle construction and primary heat flow of the OSLON LEDs

The ceramic base has the decisive advantage that it is stable with regard to light, regardless of the wavelength.
In addition, it has sufficiently good thermal conductivity and enables thermal connection to the PC board to be designed electrically neutral.

Designed for high-volume production, they can be used with all typical SMT mounting technologies and secured by means of lead-free reflow soldering.

Fig. 1: Overview of the OSLON, OSLON SSL and OSLON Square group

Cleaning

The lens of OSLON LED should not be exposed to dust or a contaminated environment. If cleaning is necessary, no pressure or force should be exerted on the lens.

Isopropyl alcohol (IPA) can be used if cleaning is mandatory. Other substances or ultrasonic cleaning of LEDs are generally not recommended.

In any case, all materials and methods should be tested beforehand, particularly as to whether or not damage is associated with the component.

As standard for the electronics industry, the use of low-residue or no-clean solder paste is suggested; PCB cleaning after soldering is then not required anymore.

Universal Solder Pad Design

In design of the solder pads for the OSLON product line, the goal was to achieve a balance between good processability, the smallest possible positioning tolerance and a reliable solder connection. In addition, however, the requirements for good thermal management should also be fulfilled.

In Fig. 3, the general optimized solder pad design with solder resist and solder paste stencil is shown for OSLON.

As illustrated, the design features three solder points: two for the electrical contacts and a central pad solely to distribute the thermal power loss.

To form a good solder joint, the aperture of the solder paste stencil has to be designed such that there is just enough solder paste on the pad. The stencil thickness used in the industrial SMT assembly process varies in the range from 100 µm to 150 µm, with typically 120 µm for the OSLON LED.

In this context however the solder paste volume has to be controlled very precisely to avoid LED tiling and to get good positioning accuracy after soldering.

Generally, the aperture design and printing process significantly affect the standoff height and ultimately the quality of the SMT assembly.

For a good thermal connection of the OSLON to the PCB it is advisable to minimize the presence of voids in all three solder joints. Total elimination is difficult, but the design of the thermal pad stencil aperture is crucial.

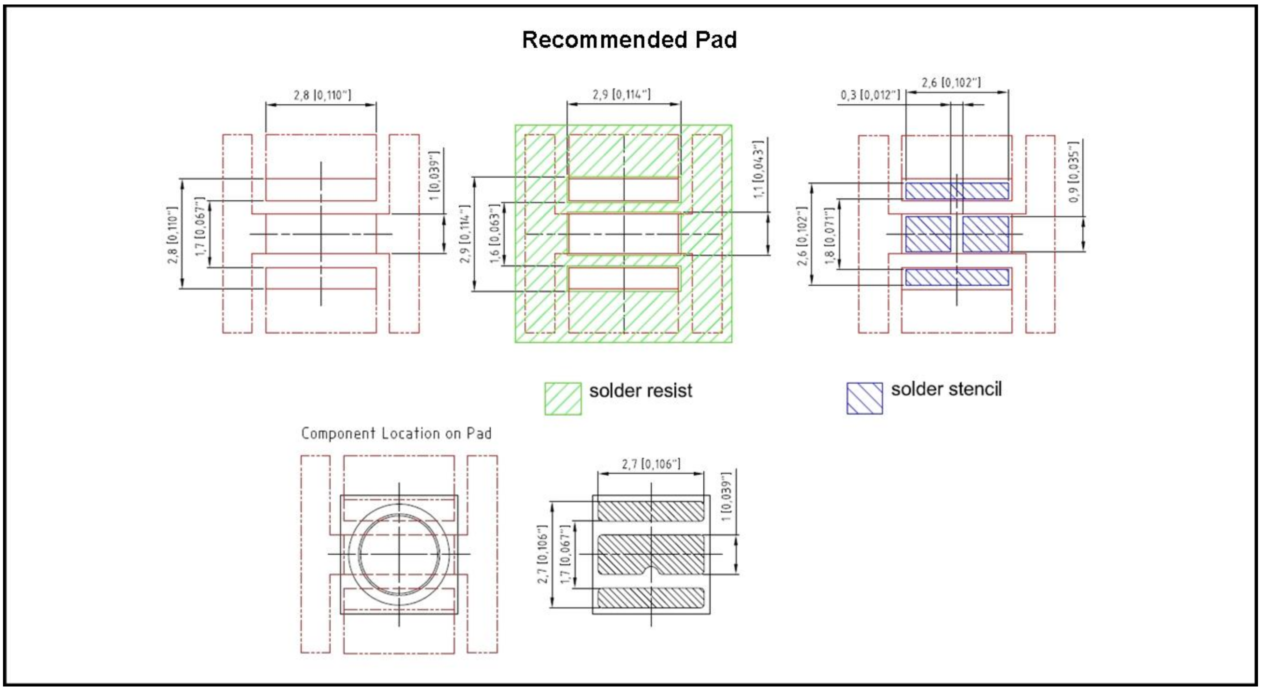


Fig. 3: Universal solder pad design of the OSLON LEDs

The proposed aperture design enables out-gassing of the solder paste during reflow and also regulates the finished solder thickness. A typical solder paste coverage of 50%-70% is therefore recommended.
The amount of voiding (e.g. verified by an x-ray image) should not exceeded approx. 30%.

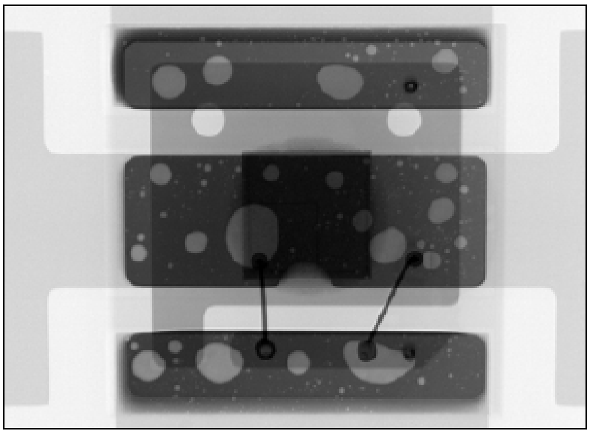


Fig. 4: X-ray image of a solder joint of an OSLON LED

OSRAM Opto Semiconductors has determined this value as a point of decreasing thermal performance, but the limit of 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.

Regarding the requirements for good thermal management of the OSLON LEDs, the copper surface around the thermal pad should be kept as large as possible. This serves for distribution and spreading of the heat and is typically covered with solder resist.

However, it should be noted that the copper surfaces around the thermal pad must be isolated from other solder pad surfaces.

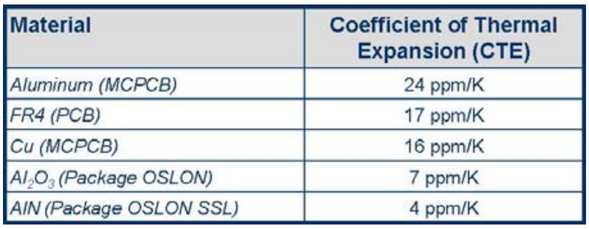
PCB material

In addition to their primary function as a mechanical fixture and electrical connecting element for the components, modern PCBs also serve to ensure stable conditions within the circuit and to provide efficient dissipation of the heat that is generated, especially when working with high-power components.
The selection of appropriate materials for the circuit board is therefore of the utmost importance, especially as the total thermal resistance of the system should be as low as possible. Materials with insufficient thermal conductivity can lead to an impairment of reliability or restrict operation at optimal performance, since the heat cannot be dissipated in sufficient quantities away from the LED.

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

- FR4 with thermal vias
- Flexible PCB on metal base
- Copper metal core PCB (IMS-PCB)
- Ceramic substrate

If an MCPCB or IMS (Insulated Metal Substrate) is used, the difference in the coefficients of thermal expansion (CTE) between the OSLON and the IMS PCB creates a stress on the solder joint; Cu is therefore preferred over Al as base plate material, because of the lower CTE.



Material	Coefficient of Thermal Expansion (CTE)
Aluminum (MCPCB)	24 ppm/K
FR4 (PCB)	17 ppm/K
Cu (MCPCB)	16 ppm/K
Al_2O_3 (Package OSLON)	7 ppm/K
AlN (Package OSLON SSL)	4 ppm/K

Table 1: CTE values of relevant materials

Compounds of thin flexible circuit board material and metal base units are also suitable. The combination with flexible circuit board material additionally offers the advantage that three-dimensional light source designs are possible, for example.

Standard substrates such as FR4 are normally not suitable for use with high-power LEDs such as the OSLON line, due to their low thermal conductivity.

However, thin double-sided FR4 material (0.4 mm ≤ d < 1.0 mm) in combination with plated through-holes (thermal vias) and additional cooling shows that this type of design can also be used, if a good thermal path through the FR4 material can be ensured.

The vias take over the heat dissipation function, thereby improving in an ostensible manner the thermal resistance of the FR4 material in the vertical direction in a targeted and localized way.

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 20-25 µm copper have become established; greater wall plating thicknesses are also 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.

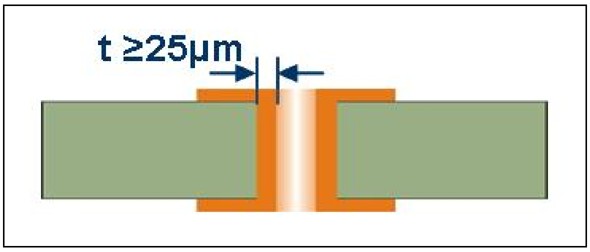


Fig. 5: Schematic layout of a thermal via

For the thermal vias, two types are possible:

- simple open PTH (plated through hole) vias (Fig. 5)
- vias which are filled with epoxy and then capped with copper (Fig. 6)

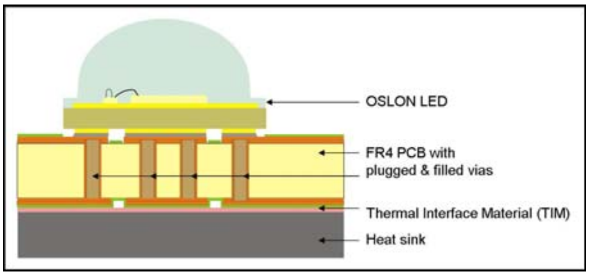


Fig 6: Schematic setup of an OSLON LED on FR4 PCB with plugged & filled vias

The use of thermal conductive silver pastes for filling to improve the thermal conductivity of the vias shows in practice only a minor thermal effect but increases the costs. For economic reasons it is therefore more sufficient to enlarge slightly the copper thickness in the hole.

The filled, copper-capped vias have the important advantage that they can be arranged directly under the thermal solder pad of the LED which means they can directly pass on the heat. The copper plugging thereby prevents uncontrolled solder wicking / solder voiding during reflow soldering which occurs at open vias (solder run-off).

Uncontrolled solder wicking generates solder balls at bottom side of the PCB (Fig.7) which leads to an insufficient thermal connection between PCB and heat sink.

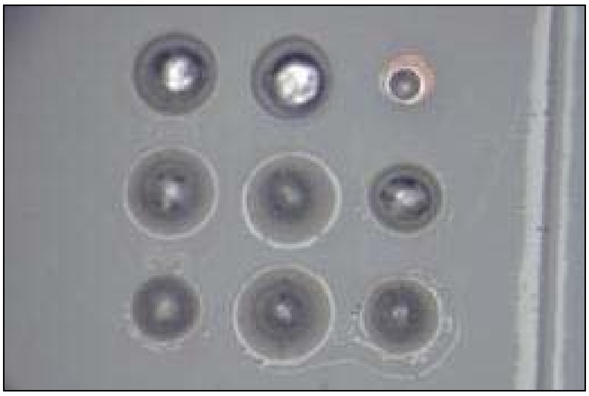


Fig. 7: Unfilled thermal vias show solder wicking, if they are used in solder pads

In many cases, however, simple thermal vias are sufficient to achieve a clear reduction in thermal resistance down to the targeted value.

The level of the resulting thermal resistance is affected by the number and position of the vias. The closer the vias are located to the heat source, the better and more quickly the heat can be dissipated and the lower the thermal resistance (Fig. 8).

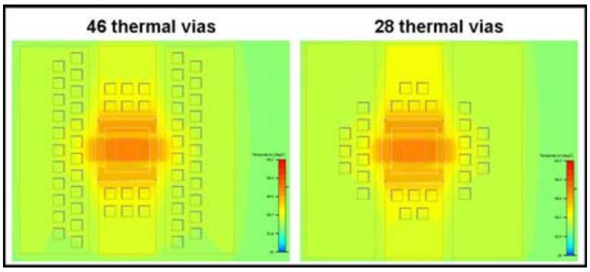


Fig 8: Comparison of the effect of two different configurations of the thermal vias

As a general rule for this layout, it is also advisable to design the copper surface around the thermal pad to be as large as possible, in order to achieve sufficient heat distribution across the FR4.

Basically, the thickness of the FR4 PCBs should also be minimized as far as possible, because the thermal resistance is directly proportional to the thickness of the material.

This means: the thicker the material, the greater the thermal resistance.

Fig. 9 shows an exemplary comparison (simulation) of the thermal resistances of different OSLON systems with a metal core PCB, a simple double-sided FR4 material and double-sided FR4 with various numbers or types of thermal vias.

Based on the setup and the results a thermal resistance for each individual PCB design ($R_{th,PCB}$) can be inferred (Fig.10).

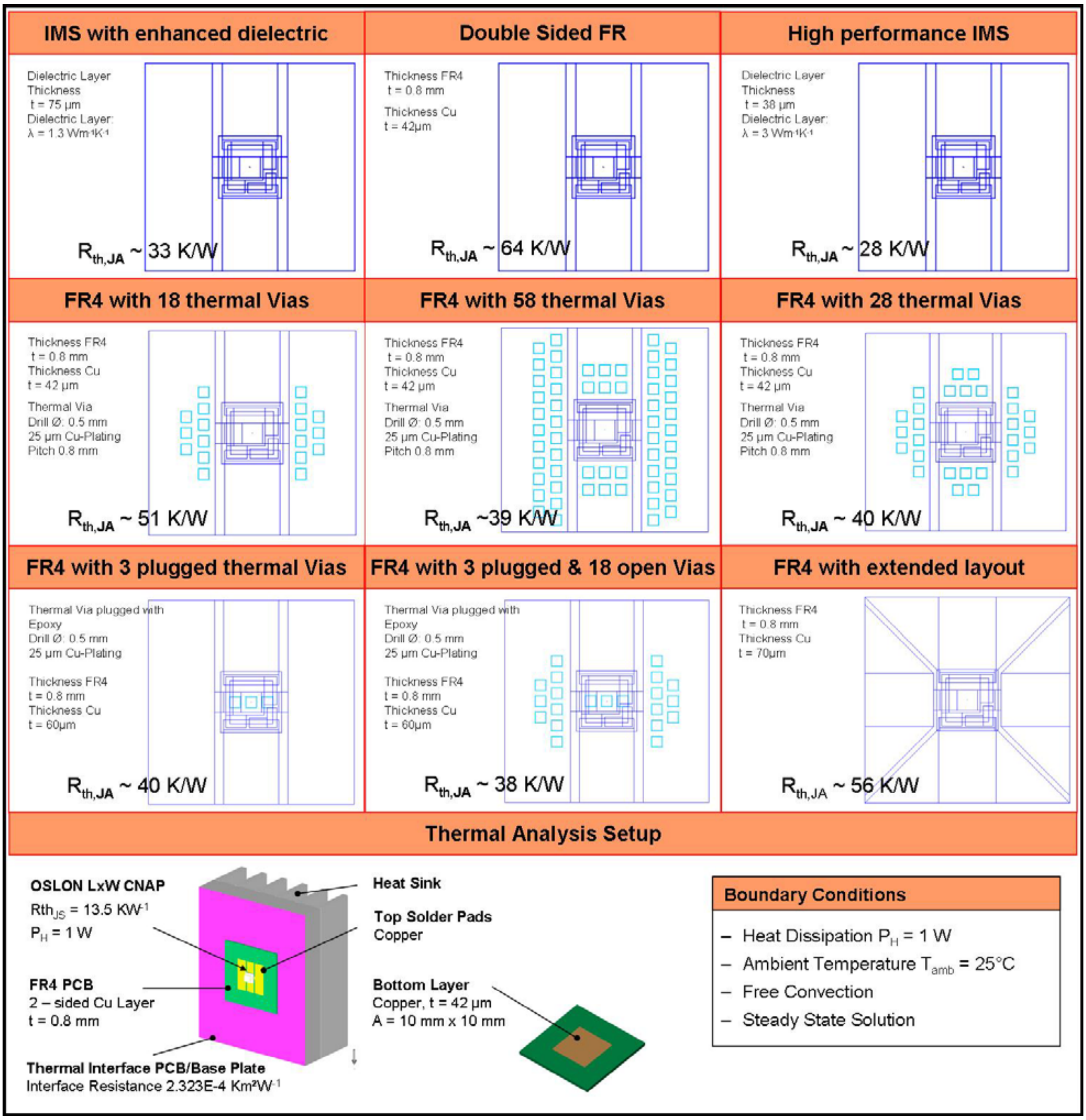
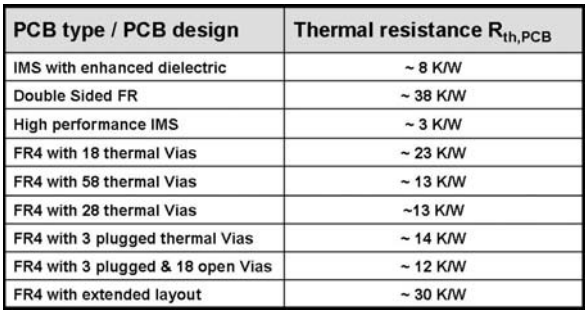


Fig. 9: Comparison of thermal resistances ($R_{th,\ Junction\text{-}Ambient}$) of an OSLON system with various FR4s with differing numbers or types of vias, a simple FR4, and an MC PCB



PCB type / PCB design	Thermal resistance $R_{th,PCB}$
IMS with enhanced dielectric	~ 8 K/W
Double Sided FR	~ 38 K/W
High performance IMS	~ 3 K/W
FR4 with 18 thermal Vias	~ 23 K/W
FR4 with 58 thermal Vias	~ 13 K/W
FR4 with 28 thermal Vias	~13 K/W
FR4 with 3 plugged thermal Vias	~ 14 K/W
FR4 with 3 plugged & 18 open Vias	~ 12 K/W
FR4 with extended layout	~ 30 K/W

Fig 10: Inferred thermal resistances $R_{th,PCB}$ of the specific PCB designs for the OSLON LEDs

The design of the pad is based on the common fundamental design for OSLON LEDs.
Typically, a diameter of 0.5 mm, a copper thickness of 25 µm in the hole, an overall plating of 42 µm and a PCB thickness of 0.8 mm are used for the via design.

The simulations also show that there are limits regarding further thermal conductivity optimization for the design of FR4 with thermal vias.

For an OSLON LED design with thermal vias located on the electrical contact pads, however, it must be considered that the electrical potentials are transferred to the back of the FR4 through the vias.
It is therefore necessary to electrically isolate the rear side of the FR4 from the heat sink for example using Thermal Interface Material (TIM).

Since the PCB design, construction and material are essential for an optimized thermal design, it is therefore advisable to verify the total system, in order to improve the operational characteristics of the LED.

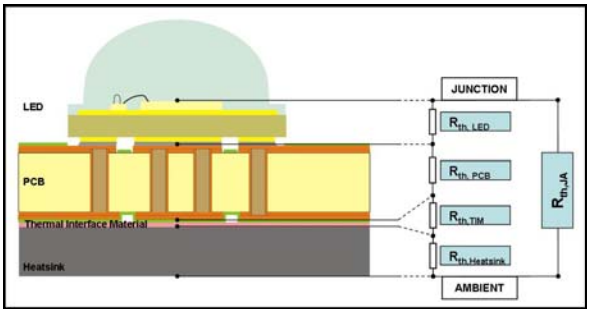


Fig. 11: Overall thermal resistances of an OSLON system

Second Level Reliability

The term "second level reliability" usually appears in connection with the requirements and characteristics of the application or of the overall system (Fig. 12). It ultimately however refers to the reliability of the solder connection between the component (e.g. LED) and the printed circuit board (PCB) or carrier substrate.

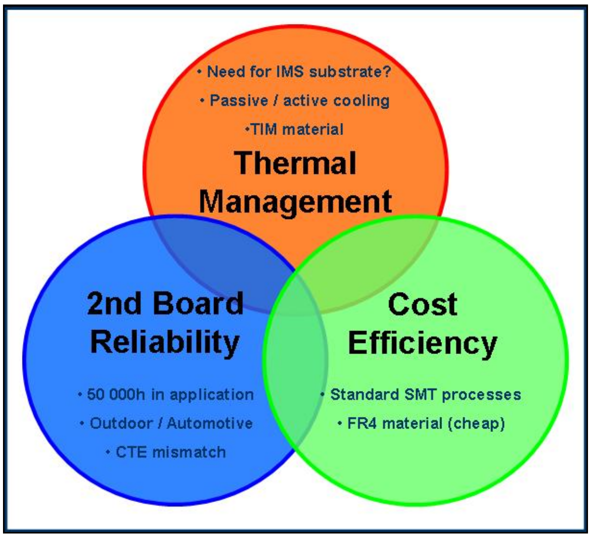
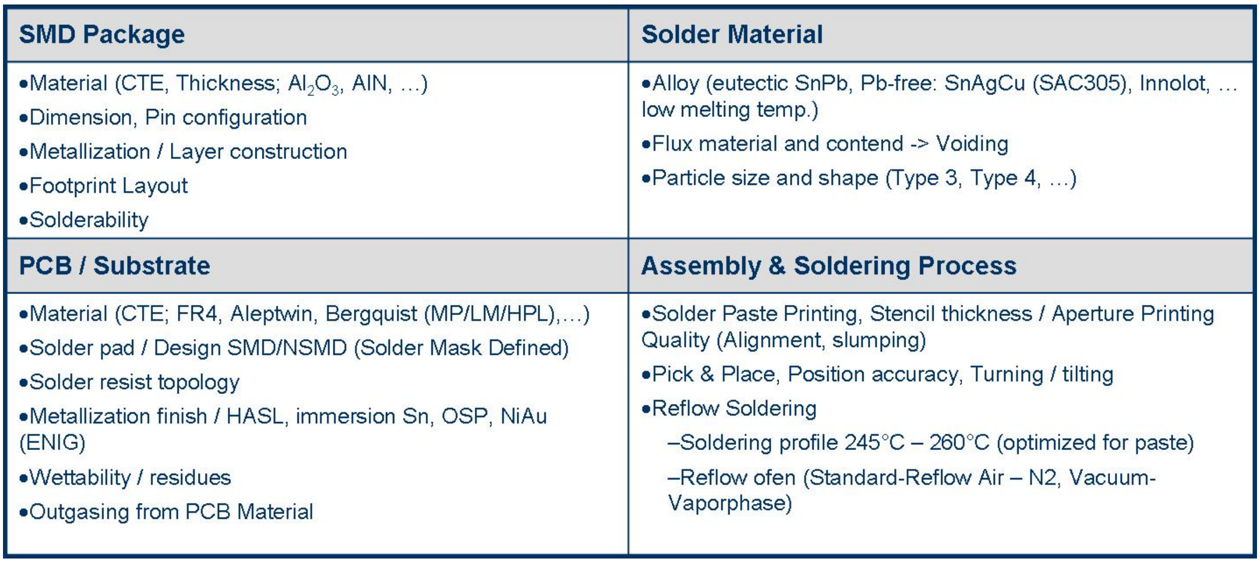


Fig. 12: Requirements and properties for efficient system design

The reliability of the soldered joint itself is determined or influenced by various factors, e.g. the component housing, the solder, the mounting and soldering process and the printed circuit board (Fig. 13).

This influence can take place either directly at the system development stage, e.g. an unsuitable combination of SMD package and PCB material (CTE mismatch), or when the individual components are processed, e.g. misalignment due to insufficient accuracy in assembly.

With LEDs with ceramic carrier substrate, such as OSLON, OSLON SSL or OSLON Square, the aspect of second board reliability should therefore be considered when selecting the PCB type, or the possible effects should be borne in mind.



SMD Package	Solder Material
•Material (CTE, Thickness; Al_2O_3, AlN, …) •Dimension, Pin configuration •Metallization / Layer construction •Footprint Layout •Solderability	•Alloy (eutectic SnPb, Pb-free: SnAgCu (SAC305), Innolot, … low melting temp.) •Flux material and contend -> Voiding •Particle size and shape (Type 3, Type 4, …)
PCB / Substrate	**Assembly & Soldering Process**
•Material (CTE; FR4, Aleptwin, Bergquist (MP/LM/HPL),…) •Solder pad / Design SMD/NSMD (Solder Mask Defined) •Solder resist topology •Metallization finish / HASL, immersion Sn, OSP, NiAu (ENIG) •Wettability / residues •Outgasing from PCB Material	•Solder Paste Printing, Stencil thickness / Aperture Printing Quality (Alignment, slumping) •Pick & Place, Position accuracy, Turning / tilting •Reflow Soldering –Soldering profile 245°C – 260°C (optimized for paste) –Reflow ofen (Standard-Reflow Air – N2, Vacuum-Vaporphase)

Fig. 13: Influencing Factors on 2nd Board Reliability

If for example an OSLON LED is soldered onto an aluminum MCPCB, temperature changes will result in thermo-mechanical stressing of the soldered joint, due to the difference in the CTE and the material strength. This leads to gradual fatigue and aging of the joint and – depending on the level of stress – sooner or later to a functional failure, owing to loss of mechanical, electrical and thermal contact (Fig. 14).

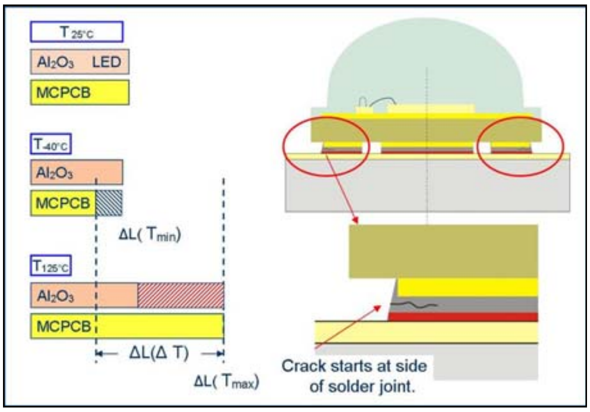


Fig. 14: Cause and effect of thermo-mechanical stress on the solder joint as a result of CTE and stiffness mismatch

In order to verify the reliability of soldered joints on microelectronic systems and components, standardized test methods (temperature change tests) are usually applied in industry. A conceivable criterion in assessing soldered joints is the shear force required to rip the components from the PCB or from the carrier substrate.

As aging/fatigue progresses, and depending on the stress parameters and the material combination, a symptomatic reduction in the shear force becomes evident, allowing conclusions to be drawn regarding the extent of damage and ultimately the reliability of the soldered joint.

Fig. 15 shows, for the combination OSLON LED with Al_2O_3 ceramic substrate on a MCPCB (aluminum) or on a FR4 PCB with lead-free standard solder (SAC SnAgCu), the proportional reduction in shear force under exemplary conditions of maximum temperature change from -40°C to +125°C and 1500 cycles.

The difference between the two systems is clearly recognizable.

Whereas with the combination OSLON with MCPCB the shear force has dropped by as much as 70% after 1000 cycles, and continues to decrease (after 1500 cycles down to 20%), the OSLON on FR4 joint is substantially more robust and reliable. Here, the loss of shear force is about 20%; it lessens only slightly after further cycles.

In terms of second level reliability, the system OSLON on FR4 PCB is therefore for these conditions notably more stable and reliable.

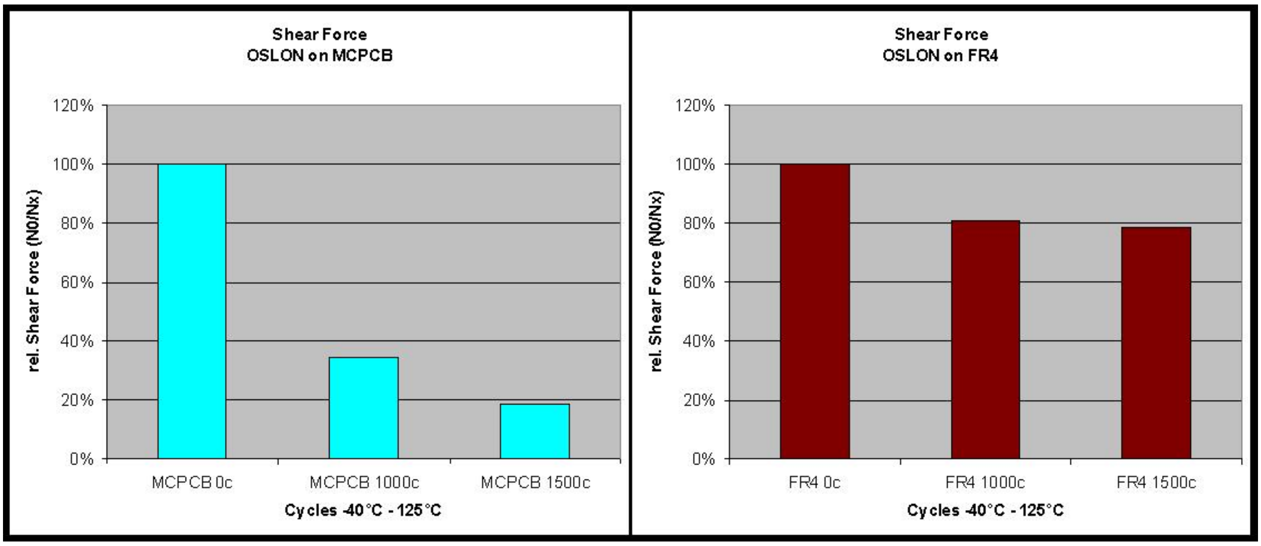


Fig. 15: Comparison of relative decline in shear force, taking the examples of OSLON LEDs on a MCPCB (Al) or on a FR4 PCB with lead-free solder, under conditions of maximum temperature change -40°C/+125°C and 1500 cycles

As the damage is influenced largely by the extent of temperature change and also by the specific temperature(s) within the range, it is generally advisable to test and adapt the application in accordance with your individual conditions and requirements.

New lead-free solder materials, e.g. INNO solder (SAC solder with additives such as Ge, Bi) or IMS carriers with specially adapted dielectric strengths, offer further potential for improvement.

Conclusion

Generally, all OSLON LEDs are compatible with existing industrial SMT processing methods, with the result that all current populating techniques can be used for the mounting process.
The OSLON LEDs impose no exceptional requirements in terms of processing.
However, regardless of the application area, it is advisable to dissipate the heat from the OSLON LED through appropriate thermal management. Above all, this is important in order to achieve optimal performance and reliability of the OSLON LEDs and the system.

OSRAM OPTO Semiconductors can nevertheless support its customers during their development and design processes in finding the best solution for their specific applications.

Appendix

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