Manual Lead-free Soldering of LEDs from OSRAM Opto Semiconductors

Application Note

Abstract

In addition to a brief fundamental consideration of the manual lead-free and lead-containing soldering process, this application note describes the essential influencing factors and their effect on the lead-free soldering process.
Furthermore, the basic rules and specific guidelines associated with the new manual lead-free soldering process are illustrated.
Also, possible risks are discussed and the general procedure of the lead-free soldering process is described.
In conclusion an overview of the solderability of the various LED types from OSRAM OS are presented, along with their ability to be reworked and repaired.

Introduction

With the introduction and ratification of Directive 2002/95 (RoHS directive "on the restriction of the use of certain hazardous substances in electrical and electronic devices") as of June 2006, many production lines have already switched to lead-free, RoHS-conformant technology or are currently still in a transition phase, in which both lead-free and lead-containing processes are executed in parallel.

In automated production sequences, the implementation of lead-free soldering processes has been carried out without great difficulties, in spite of the smaller processing window due to the higher melting temperature of the new solder.

The quality, reproducibility and process stability have achieved an equally high level, although the solder heat resistance of individual SMD components such as LEDs makes it difficult to conform to the lead-free soldering process.

In contrast, the introduction of a manual lead-free soldering process is still awkward, since it is more difficult to control.
Although today, manual soldering is almost exclusively used for the manufacture of prototypes and for repair or rework of production components, quality assurance represents the greatest challenge, here.

With manual lead-free soldering, the quality is therefore essentially influenced and determined by the solder materials and equipment, the experience and ability of the operator and a continuous process control.
It is therefore recommended to only carry out manual lead-free soldering with appropriate equipment and trained personnel.

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In addition, it should be noted than not all available LED types are suited for manual soldering or repair.

Underlying considerations

In principle, manual soldering with lead-free solder is not much more difficult than soldering with lead-containing solder.
In order to achieve good results and solder connections, the properties and differences of the two soldering processes must be thoroughly understood and considered from a technical standpoint.

The essential differences between lead-free solder and tin-lead compounds is first of all, the higher melting temperatures (up to 40°C higher than tin-lead compounds, depending on the solder used), and secondly, the poorer wetting characteristics of lead-free solders.
For soldering, this means that the time required for wetting the solder joints increases and the lead-free solder takes longer to spread.
In addition, differences can arise in the appearance of the solder joints; lead-free connections appear to be dull and matt (without luster) in comparison to lead-containing solder connections.

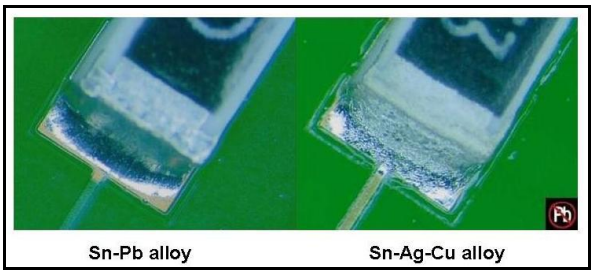


Figure 1: Different appearance of lead-containing and lead-free solder

The quality and steadiness of soldering created manually with a soldering iron is generally influenced by several factors, including:

- the composition of the solder
- the activity of the flux material
- the thermal characteristics of the soldering iron
- the angle of soldering, dependent on the handling of the operator
- the joint clearance of the two surfaces

In addition to the abovementioned factors, the solder connection is ultimately dependent on the prevailing temperature and effective time.

Important influencing factors and their implications

Solder

The type of solder used represents the most important parameter and has a decisive influence on the entire soldering process and on the subsequent connection.
Through the composition of the solder and the associated properties such as solder temperature, wetting and oxidation characteristics etc, a certain process window for the soldering process is predefined.

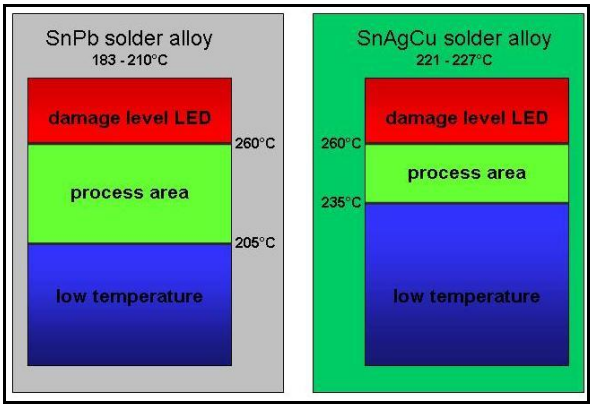


Figure 2: Side by side comparison of the process windows – lead-containing vs. lead-free

As can be seen in Figure 2, the higher melting point of the lead-free solder leads to a reduction in the solder processing window in comparison to that of lead-containing solder.
The size of the window is determined by the melting temperature of the solder and the maximum allowable temperature, above which damage to the component occurs.
In addition, the poorer wetting characteristics

of lead-free solder causes a lengthening of the processing time. Compared to lead-containing solders, a factor of 2 to 3 can be assumed.

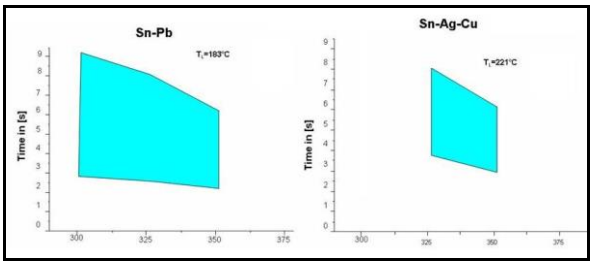


Figure 3: Side by side comparison of the process window – lead-containing vs. lead-free hand soldering

Flux material

The use of a flux material basically serves to activate the respective soldering surfaces of the components.
That is, it dissolves the oxidation layer of the surfaces by warming and at the same time, prevents new oxidation of the solder, before and during the soldering process.
The flux material simultaneously reduces the surface tension of the flowing solder and in this way, brings about better wetting characteristics and a more favorable flowing property.

With the use of flux material, one generally has to consider whether the smoke gases which arise, depending on the type of flux material, represent a health hazard.
Regardless of this, it is generally recommended to provide sufficient ventilation, or for longer periods of work, to utilize an exhaust fan.

In addition, flux material also has an influence on the durability of the soldering iron tip. Since this flux material is more aggressive than tin-lead compounds, a reduction in operating life can occur. As a result, the tip must be exchanged after a shorter period of time.

Type of soldering iron

Many types of soldering irons are available. The main differences are the heating power and the precision of temperature regulation.

With older soldering iron models, temperature measurement and regulation usually occur at the internal heating element. Due to the distance from the soldering tip, large deviations from the actual temperature of the soldering tip (up to 50°C) can occur.
Combined with the higher melting temperature of lead-free solder, this increases the risk of overheating or can lead to temperature losses during the manual soldering process.

Better results can be achieved for lead-free solder with the help of modern soldering stations which possess regulated heat management as well as internal process monitoring.
With modern soldering irons, temperature regulation occurs at the soldering tip rather than at the heating element. In addition, the soldering irons are equipped with sufficient heating power (> 80 W) and exhibit extremely fast warming characteristics.
This ensures that all solder joints are created with nearly the same temperature.

Solder temperature

In general, it is recommended to use the lowest temperature possible, depending on the solder used.
On the one hand, this prevents damage to heat-sensitive components and on the other the operating life of the soldering iron is extended.

With an increase in temperature, the wetting time for lead-free solder can indeed be reduced, but this can damage certain types of components and reduce the operating life of the soldering iron.

Since the melting point of lead-free solder is around 40°C higher than the melting point of typical tin-lead compounds, the temperature of the soldering tip must be set higher as a consequence.

In general, therefore, it is typical and also acceptable that the temperature of the soldering tip is set to be 50°C higher than the melting point of the solder. However, soldering temperatures are often selected which are 100°C higher than the melting temperature.
This excess temperature is ultimately dependent on the heat capacity of the LED to be soldered, the extent of the solder joint and the size of the soldering tip.

Possible problems / risks

Prototyping
With manual soldering, the most common problems are damaging the LEDs or the circuit board (base material, solder resist mask, pads etc.) and poor solder joints.
Soldering of larger LEDs with a higher heat binding potential causes the greatest difficulty in most cases.
An improvement can possibly be achieved with the use of an additional heat source (heating pad, IR radiator, etc.).

Poor solder joints most often occur if the surfaces are not clean or are strongly oxidized.
With lead-free compounds, this is seen more often.
One possible remedy is the use of an aggressive flux material. However, this can lead to additional problems.
Since solder wire is produced with several types of flux, some of which are more corrosive than others, an initial test should be performed with respect to its suitability.
A further possibility is the use of an additional flux material for the components.

Rework
When reworking components already soldered with lead-free solder, it should be noted that not all alloys can be mixed together. Some combinations can lead to unreliable solder connections.
Normally the same alloy as for to the former soldering is used.

In case different alloys are used in parallel, it would be advantageous to mark or label the solder pads and possibly the components, in order to provide information about the solder used.

Since a higher temperature is required during rework due to a change in the composition of the material, it can happen that both the components and circuit board can be damaged in the process. Careful, skilled work along with process and temperature monitoring are thus strongly recommended.

Furthermore, depending on the condition and storage time of the components to be processed, a more aggressive flux material may possibly be required.

Basic rules for manual soldering

- A good heat contact between the soldering tip and the solder joint (component and PCB) must be created. This can only be achieved with flowing solder.
- The flux material should perform its effect at the appropriate locations and should therefore flow freely to the locations to be soldered. This also enhances the heat transfer.
- The contact between the soldering iron and the location to be soldered should only be maintained until the solder has freely flowed.
- Only as much solder as needed should be used. For stranded-wire connections, the contour of the wires should remain visible.
- The LEDs must not be permitted to move during the solidification process.

Additional rules for lead-free soldering:

- The temperature of the soldering tip must be raised in comparison to that required for lead-containing solder (+25°C to +40°C)
- The upper limit must not be increased, as this would result in delamination of the circuit board or thermal damage to the components. For the soldering procedure, this means that the processing window becomes narrower.
- With lead-free solder, the flow behavior is poorer; the solder time increases by 50 – 100% in comparison to lead-containing solder.
- Exertion of pressure during soldering should be avoided so that the soldering tip does become deformed or the components will damaged.
- Since lead-free solder is more aggressive, there is more wear and tear on the soldering tip. The soldering stations should be switched off when not in use or when no standby function is available.
- The use of fast heating soldering tips is preferable, since these are more quickly placed into operation.
- After the soldering the tip should be cleaned and tin-plated.

Lead Free Hand Soldering Process

In general, it is recommended to prepare and provide all necessary tools, materials and additional auxiliary tools before the soldering process.

This also means that the circuit board should be cleaned if necessary, in order to remove oxidation or other impurities.
Care should be taken that cleansing itself does not cause damage to the circuit board or circuit traces which could interfere or inhibit the wetting of the solder.
In order to minimize or prevent additional effort, it is advantageous to populate new circuit boards directly after manufacture, or package them in a vacuum or inert gas for later processing.
Contamination or progressive oxidation is thereby prevented.

In case of rework of already populated boards, this means that if necessary, the boards should be preheated in an appropriate oven, depending on storage conditions and time.
Preheating serves to remove absorbed moisture and prevent the so-called "popcorn" effect with components.
The duration and temperature of the preheating procedure is individually determined, dependent on the components on the circuit board and the storage and environmental conditions.

Tools and materials

As mentioned previously, lead-free solder places special demands and requirements on the soldering equipment.
Representative of equipment available on the market, three appropriate and proven soldering stations are listed here.

ERSA:
i-CON Soldering Station & i-Tool Soldering Iron, 150 W

WELLER:
WD2M Soldering Station, 160 W

METCAL:
Soldering Station PS 800

All three systems were specially developed and optimized for lead-free soldering.
In comparison to older soldering stations for example, the soldering system from ERSA possesses precise temperature regulation at the soldering tip and extremely fast warm-up characteristics. In addition, it is equipped with a process window alarm and an

automatic standby sensor as well as other user-friendly functions.
Other systems are similarly equipped.
For the soldering irons mentioned above, several different soldering tips are also available which can be specifically adapted and optimized for the component.

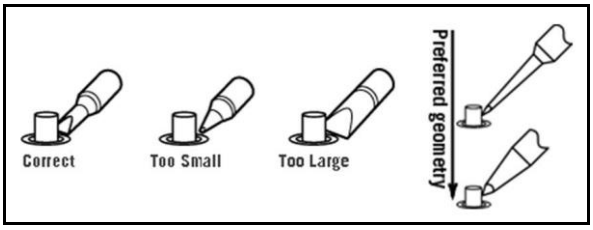


Figure 4: Tip Selection- correct geometry for each application

As auxiliary tools, various sizes of tweezers are recommended for better handling of LEDs along with a desoldering braid or pump for removal of solder during repair work. In addition, the use of a so-called "third hand", an adjustable fixture for holding the circuit board, and a magnifying glass can also be helpful.
In general, ESD protection should additionally be provided for the components and/or the populated circuit board. This can be achieved with a grounding armband, grounded table or support, etc.
When soldering, the use of solder wire with flux core is preferable. This is available in several diameters and provides a sufficient amount of flux in most cases.

As an example, solder wire from EDSYN consisting of SnAgCu with NO-CLEAN flux as per F SW34 can be used.
For soldering of LEDs, particularly for miniature components, a diameter of 0.35 mm is sufficient.
Depending on the size of the LED or component to be soldered, heavier solder wire can be used.

With the use of solder wire with a flux core, the solder and flux can spray out due to the very quick warming of the solder.
The flux tends to carbonize in the process and the desired effectiveness is reduced. An improvement can be achieved with a V-formed notch in the solder wire, permitting more effective use of the flux material.

General solder technique / procedure

The soldering technique and correct procedure is basically no different from the old technique for lead-containing solder.

After setting the required working temperature (soldering tip ≤ 350°C for LEDs) the tip should be cleaned before each use with a moist sponge or by means of a dry pad made of steel wool.

Figure 3: Example of moist sponge for cleaning soldering tips

Dry cleaning has the advantage that the soldering tip is not abruptly cooled, and that no contamination arises from dirty sponges.
In addition, the light scouring effect of steel wool can also easily remove heavy contamination and accumulated passive layers.

Figure 4: Example of dry cleaners

After cleaning, the tip must be wetted again with a sufficient amount of solder.

In the next step, the solder joint is heated. Here, the solder pad and LED connection contact are heated together by simultaneous contact with the soldering tip.

The LED is then attached with the addition of a small amount of solder in the corner between the soldering tip and the LED pin.
Afterwards, the solder wire should be pulled away and one should wait for a short moment.
Then, solder is again applied to the lead or solder joint until the location has been sufficiently filled with solder.
The solder wire is then pulled away and finally, the soldering tip is removed from the solder joint.
The other contact connections are soldered in a similar manner.

Before replacing the soldering iron in the holder, the tip should be checked once again and re-tinned if necessary (procedure according to the IPC recommendation).

Rework and repair procedure

The procedure for repair or rework of solder connections differs somewhat from the prementioned soldering technique, since the solder connection is already present.
With repair, a defective component is normally replaced with a functioning part. The existing solder connection must be melted and the solder removed by means of a desoldering braid or a pump.
With rework, however, individual solder joints are reworked because they are possibly damaged or not sufficiently formed.
Here, it is also generally true that the soldering iron tip should be cleaned and wetted with solder before use.

1. Heat the solder connection until the solder completely melts

In general, the soldering iron should be held at the connection location with the largest amount of solder. In order to achieve a good heat transfer, the tip should be simultaneously held against the solder pad and the connection contact of the component.

2a. Remove the liquid solder by means of a desoldering braid or a pump (repair)

2b. Apply appropriate solder if necessary (rework)

The solder wire is applied to the surface of the melted solder so that the solder is melted there instead of at the soldering tip.
In order to prevent damage to the component of the circuit board material, a maximum contact time of 3 seconds should not be exceeded.

3. Solidification of the solder connection

After the soldering tip is removed, the connection solidifies again after a few seconds and other leads of the component can be soldered.

4. Cleaning the solder joints

In case cleaning is required, it is recommended to eliminate the flux residue as soon as possible. As a rule, dried residue adheres more tenaciously and can only be removed with greater difficulty and by more aggressive means.

Visual assessment of the solder joints

After soldering, a visual assessment should be performed in any case, with respect to the appearance and quality of the connection.
The person carrying out this assessment should be trained in this regard and have sufficient experience. For a confident and reliable assessment, criteria according to IPC-Standard (IPC-A-610) are drawn upon worldwide.
A few excerpts include:

- The solder joint should be uniform and smooth in appearance (shiny is not required)
- The solder should taper off from the inserted parts (small contact angle)
- The surface of the solder joint should be unbroken.

- The contours of the soldered parts should be recognizable in the solder joint.
- The solder joint must contain sufficient solder.

Additional information and exact details can be obtained from the IPC Standard.

Cleaning

In most cases, final cleaning is only necessary to remove any flux residue which may be present.
Essentially, other residue or contamination should not be present.

Often, various cleansing solutions or cleaning by means of an ultrasonic bath is recommended by solder manufacturers.

With the presence of LEDs, however, this is only conditionally or not at all possible.

In principle, isopropyl alcohol (IPA) can be used, since this is also suitable and approved for cleaning LEDs from OSRAM OS.

If other cleansing solutions are applied, their suitability should be tested beforehand, particularly if there is associated damage to the LED.
Because of worldwide regulations, cleansers such as FREON or other compounds containing chloroflurocarbons (CFCs) should not be used.

Cleaning by means of an ultrasonic bath is not recommended for LEDs.
The reason for this is that the influence on the LEDs is dependent on the ultrasonic power, the duration of treatment and the cleansing solution used.
If ultrasonic cleaning cannot be avoided, it must first be determined whether the LEDs will be damaged in the process.

In the best and ideal case, cleaning is not required if solder with so-called NO-CLEAN flux is used.

With this type of flux material, it is not necessary to remove the remaining residue from the connections or circuit board in order to guarantee reliability.

It is simpler as well to resort to water-soluble flux material. Meanwhile, there are systems which also permit better wetting of lead-free materials without nitrogen.

Important LED-specific points

Since LED housings predominantly consist of plastic (and ceramic for a few of the new LEDs), the direct contact with a hot soldering tip can often lead to damage of the device.
This applies exceptionally to the plastic optics of the LEDs.

In addition, it should be noted that with higher soldering tip temperatures, heat is transferred more quickly to the housing via the connection contacts.
The prescribed solder times should therefore not be exceeded, since this can otherwise damage the component.

It should also be noted that with the various packaging types, the size and form of the connection contacts vary as well.
For optimal soldering results, it is recommended to use individually adapted soldering tips.
If a soldering tip is too large or wide for miniature components, for example, this can lead to overheating and thus damages to the component housing. If a small, narrow tip is used for larger contacts, however, insufficient heat is available for a good solder connection.

Particular experience combined with special care and higher demands are required for the processing of LED with high power housings. The reason for this is the heat slug integrated in the package base. For optimal heat transfer, this must be affixed or soldered to the circuit board.
Soldering of the heat slug itself can only occur with the help of solder paste and an additional heating plate.

Since the heat slug is embedded in the package base, direct contact with the soldering iron is not possible; for this reason, rework at the heat slug cannot be carried out.

Generally it is advisable to use an additional heating plate for lead-free soldering of LEDs, especially if an insulated metal substrate is utilized.

In the following, Table 1 provides an overview of the manual solderability of various LED types from OSRAM OS as well as their repair and rework capability.

Conclusion

Equally good results and reliable solder connections can also be achieved and created with lead-free solder.

The prerequisite for this, however, is that one thoroughly understands the properties and differences of the new solder and also considers the corresponding process from a technical standpoint.
In addition, with manual soldering, it is generally recommended to take into account the specific features of the component or LED such as the package form, lead size, etc. when defining the process window.

Basically, manual soldering with lead-free solder is not much more difficult than soldering with lead-containing solder, so long as work is performed with appropriate equipment, qualified employees and the fundamental ground rules are strictly maintained.

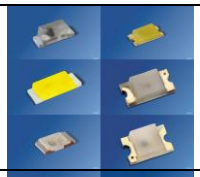
LED TYPE	EXEMPLAR	IMAGES	MANUALLY SOLDERABLE	REWORK POSSIBLE	CAPABLE OF REPAIR
Radial or Through-hole LED	3 mm ARGUS LED 4 mm OvalLED 3 & 5 mm LED 5 mm MultiLED Ultra Flux		☺	☺	☺
Miniature Components	SmartLED ChipLED		☺	☺	☺
Mini Top Looker	MiniTOPLED PointLED		☺	☺	☺
Side Looker	FIREFLY FIREFLY RGB Micro SIDELED SIDELED Multi Color Micro SIDELED Multi SIDELED MIDLED		☺	☺	☺
☺ = possible	☹ =conditionally possible		☒ = not possible		

Table 1a: Overview of manual solderability and rework/repair capability

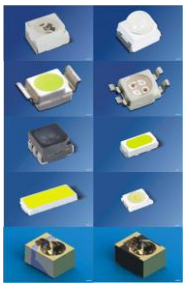
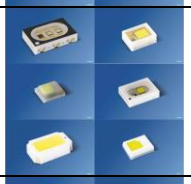
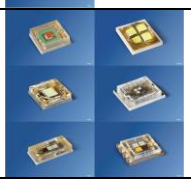
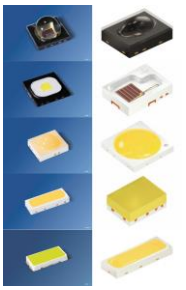
LED TYPE	EXEMPLAR	IMAGES	MANUALLY SOLDERABLE	REWORK POSSIBLE	CAPABLE OF REPAIR
Top Looker	TOPLED TOPLED with lens Multi TOPLED RG-TOPLED RG-Multi TOPLED 6-lead MultiLED 6-lead ChipLED STABLIX DISPLIX DURIS E3 DURIS S10 TOPLED Compact MIDLED		☺	☺	☺
Power LED	Power TOPLED Power TOPLED with lens Adv. Power TOPLED Adv. Power TOPLED Plus		☺	☺	☺
Ceramic LED	CERAMOS CERAMOS Flash Multi CERAMOS CURAMOS		😐 only with special equipment and solder paste	☹	😐 only with special equipment and solder paste
Ceramic LED	OSLON SX/MX/LX OSLON SSL OSLON Signal OSLON Square OSLON Compact		😐 only with special equipment and solder paste	☹	😐 only with special equipment and solder paste
Ceramic LED	OSRAM OSTAR Compact OSRAM OSTAR Lighting Plus OSRAM OSTAR SMT OSRAM OSTAR Stage OSRAM OSTAR Medical		😐 only with special equipment and solder paste	☹	😐 only with special equipment and solder paste
Epoxy SMD (Bottom only-terminated)	OSLON Black Series OSLON Black Flat TOPLED Compact 4014 DURIS P5 DURIS E5 DURIS S2 DURIS S5 DURIS S8 DISPLIX oval OSRAM OSTAR Projection Cube SYNIOS P2720 SYNIOS E4014		😐 only with special equipment and solder paste	☹	😐 only with special equipment and solder paste
Flash LED	OSLUX Platform		☹	☹	☹
High Power LED	Dragon Platform		😐 Heat slug only with solder paste	😐 Heat slug not possible	😐 only with additional heating plate
☺ = possible		😐 =conditionally possible		☹ = not possible	

Table 1b: Overview of manual solderability and rework/repair capability

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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

Revision History

Date	Revision History
Aug. 2007	Publishing of application note
March 2013	Update Table 1
Sept. 2015	Update Table 1, Change of Company Info & Disclaimer

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ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world.
For more information go to www.osram-os.com.

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