LED Assembly & Soldering

Lang Kurt Jürgen | Jan 2014 | Regensburg
Presenter: Christine Rafael / Horst Varga
Agenda

1. LED Construction / Package Variety
2. Process Flow / Solder Pad and PCB Design
3. Solder Paste Printing
4. Pick&Place / Nozzle Design
5. Reflow Soldering
6. Outlook / Additional Information
Definitions

<table>
<thead>
<tr>
<th>LED Chip/Die</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinfilm Technology</td>
<td></td>
</tr>
<tr>
<td>InGaAlP</td>
<td></td>
</tr>
<tr>
<td>red / yellow</td>
<td></td>
</tr>
<tr>
<td>InGaN</td>
<td></td>
</tr>
<tr>
<td>blue / green white</td>
<td></td>
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</tbody>
</table>

LED Package

LED Luminaire
LED Construction

High Power LED Package

Ceramic based Package

Leadframe based package

OSLON

Lens

Die

Wire Bond

Ceramic

Metallization

ESD Diode

Golden DRAGON

ESD Diode

Lead

(Cathode)

Lead

(Anode)

Wire Bond

Die

Heat sink

Package
LED Package Technology

Trend: High Power
- Power TOPLED
- Advanced Power TOPLED
- DRAGON
- OSLON

Trend: Minimum size
- TOPOLED
- PointLED
- Mini TOPLED
- Chipled
- Micro SIDELED
- SmartLED
- FIREFLY

CONFIDENTIAL
Standard SMT Prozess Flow
Solderpad Design

Parameter for solder pad design

- optimized positioning – self-centering - (no turning, no tilting) of component after reflow
- good heat distribution
- avoid solder failures (shorts, tombstoning, …)

Thermal Management

In order to distribute the heat over the PCB the Copper area should be maximized in the Layout
Features for tolerance consideration:

With optimizing solder pads and solder resist geometries, adopted stencils and good reflow profiles → good self alignment during reflow soldering:

→ Tolerance of Pads (LED) to Pads (PCB):

+/- 50 um @ 5 Sigma

SMT Reflow Solder process

Tolerance chain:

I: Hole ↔ Cu pattern
II: Cu pattern ↔ Solder resist
III: Solder resist ↔ „Floating into position“ (LED Pad – Chip/Layer)
IV: LED Pad ↔ LED Die/Layer
Solder Pad / Aperture Design

Influence Solder Pad Design <-> LED Position

**SMD**
- Solder pad + Rand (LS)
- Solder Pad = foot print
- Bauteil Foot Print + 50µm (3 Seiten)

**HalfSMD**
- Lötpad orientiert sich an Cu Kante
- Lötpad orientiert sich an Cu Kante + Rand
- component foot print + 75µm (umlaufend)

Cu solder pad
Cu area covered with solder resist or solder mask

Foot print
Solder mask

Tolerance chain: reference hole – Cu pattern – solder resist mask – self alignment LED
OSLON Compact
Solder Pad / Aperture Design

Tilting

Aperture design 1:1
120µm

Aperture design 2 pads
100µm

Higher risk of tilting

No tilting

-> optimized stencil aperture and thickness
+ use planar PCB Finish (no HASL!)
Solder Pad Design

Self-centering or self alignment

For optimization of LED positioning the self-centering effect during reflow can be used.

**NSMD Non Solder Mask Defined or HalfSMD or copper defined layout is recommended**

LED will be aligned centric on the pad because of symmetrical wetting forces.

**Self-centering effect at symmetric LEDs**

With the self-centering or self alignment effect it is possible to get a position accuracy to a reverence point (Fiducial Mark) of $\pm 0.1 \text{mm}$ for symmetric components.
Solder Paste Printing

The application of solder paste has a significant influence on the solder quality, it causes around **60 - 70% of all failures** in the SMT assembly process flow.

**Failure distribution SMT process**

- 64%
- 15%
- 15%
- 6%

**pick & place**

**reflow**

**solder paste printing**

**other**

Source: C.H. Mangin

**Requirements for a proper solder printing**

- Exact positioning (alignment of solder deposit to pad/lands)
- accurate geometry, defined edges
- Exact deposit volume, no doggy ears
- No smearing or solder lump
Stencil Design

- The printed solder volume deposit is determined by the stencil opening (aperture) and the thickness of the stencil.
- The solder-joint thickness (standoff height) of SMT LEDs should be typically between 45 µm to 75 µm.
- Stencil thickness used in SMT industry varies from 100µm to 150µm (0,004in to 0,006in) range, with typically **OSRAM Opto Semiconductors use and recommend 120µm** for SMT LEDs.

The actual used stencil thickness depends on the other SMD components on the PCB.

Example Golden DRAGON

**tilted Golden DRAGON caused from excessive solder**
Aperture Design / SPI Solder Paste Inspection

Stencil design: Example for OSRAM OSTAR Compact

Electrical Pads: Anode/Cathode
Reduction afloat 50µm – 100µm compared to solder land

Heat Spreader / Thermal Pad
Reduction of 30% - 40% compared to solder land

Anode Pad

Thermal Pad or Heat Spreader electrically isolated

Cathode Pad

For process evaluation / control and failure prevention it is recommended for all LEDs with exposed heat spreader (thermal pad) like Golden DRAGON, OSLON, OSRAM OSTAR SMT/Compact, to check regularly (SPI) the solder paste volume under the heat spreader.

proper solder paste print
**Voiding / Stencil Aperture**

**Voiding**

- Voids have a significant influence on the second board reliability
- Voids in solder joints tighten the problem of local unbalanced spread of electricity and heat -> hot spots

Because of an optimized aperture-design for all large area solder lands (heat spreader) the voiding can be minimized. A design with smaller multiple openings in the stencil enables an out-gassing of the volatile solder paste/flux materials during the reflow soldering.

**Max. Void area**

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

Whereas in internal studies and simulations OSRAM Opto Semiconductors determined a maximum up to 50% of voids in the thermal pad which have only 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 used PCB materials.
Handling and Storage

Wrong Storage and Handling

In general, the use of all types of sharp objects should be avoided in order to prevent damage of silicon encapsulate, lens, or the glass cap, since this can lead to a optical degradation or complete failure of the component.

PCBs or assemblies containing LEDs should not be stacked in a way that force is applied to the LED, or should not handled directly on the LED.

For correct handling pick the LED only on the ceramic base.

Incorrect, don’t touch the lens!

For manual assembly and placement the use of so-called vacuum tweezers is recommended.

Generally, all LED assemblies should return to room temperature after soldering, before subsequent handling, or next process step.
Pick & Place

Pipette / Nozzle / Pick-up Tool

When processing in automatic pick & place machines care should be taken to:

- appropriate Pipette / Nozzle / Pick-up Tool
- conform process parameters like placement force (max. 2N)

For additional detailed information see App. Note:

Recommended Pick & Place Tools (Nozzles) for LEDs of OSRAM Opto Semiconductors

Example: Nozzle recommendation
Pipette / Nozzle / Pick-up Tool Design

Considerations for Vacuum-Nozzle design

• Package Type / Geometry
  - Plastic housing with reflector (pick-up collar)
  - Ceramic substrate / LED-die / Silicon casting
  - Flat casting
  - Lens

• Casting / Lens material
  - Resin
  - Plastic (PC, Epoxy, …)
  - Silicone (different hardness, sticky)

• Avoid air-leakage

• Tape pocket (Dimension)

• Nozzle material / Manufacturing / Cost
  - plastic, metal, ceramic, …
  - abrasion
Customized LED nozzle

Examples

Lead frame based reflector package with planar resin

⇒ Adopted Nozzle geometry prevents
  ✓ Damage (crack, scratches, …) of casting area
  ✓ Brocken bond wire
  ✓ LED sticks on Nozzle
Customized LED nozzle
Examples

Ceramic substrate with molded silicon lens, different lens geometries

- Adopted Nozzle geometry,
  - No damage of primary optics (lens) and bone wire
  - No sticking (silicone lens; tackiness, different hardness)
  - No tilted pick-up

OSLON Familie
Customized LED nozzle
Examples

White SMD reflector package with clear silicone lens

⇒ Adopted Nozzle geometry
  ✓ No damage of primary optics (crack, scratches, …)
  ✓ With flattened sides smooth step in tape pocket

Golden DRAGON oval Plus
Reflow Soldering

Basics

- In mass production **Convection Reflow Soldering** (with **forced air or nitrogen convection**) is the most common reflow method. For superior solder joint connectivity results it is recommend soldering under standard nitrogen atmosphere.

- Basis and reference point for reflow soldering is the JEDEC standard **J-STD 020D.01**

- Because of **different board designs** use **different** number and **types of components, solder pastes, reflow ovens, and circuit board materials and designs**, no single temperature profile works for all possible combinations.

- OSRAM OS recommends to follow the recommended soldering profile provided by the **solder paste manufacturer**, and do a further optimization according the needs of the actual used board.

For additional detailed informations see App. Notes:

**Further Details on lead free reflow soldering of LEDs**

**Measuring of the Temperature Profile during the Reflow Solder Process**
Reflow profile data sheet recommendation

- Preheat
- Flux Activation
- Melting Temp. of Solder
- Reflow
- Cooling

**Temp T [°C]**
- 217°C
- 240°C
- 245°C
- 25°C

**time t [sec]**
- t_P
- t_S
- t
## Reflow profile data sheet recommendation

<table>
<thead>
<tr>
<th>Profile Feature</th>
<th>Recommendation</th>
<th>Max. Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pb-Free (SnAgCu) Assembly</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ramp-Up Rate to Preheat *)</td>
<td>2°C/sec</td>
<td>3°C/sec</td>
</tr>
<tr>
<td>25°C to 150°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (t_S) from (T_{S_{\text{min}}}) to (T_{S_{\text{max}}}) (150°C-200°C)</td>
<td>100s</td>
<td>min. 60sec max. 120sec</td>
</tr>
<tr>
<td>Ramp-Up Rate to Peak *)</td>
<td>2°C/sec</td>
<td>3°C/sec</td>
</tr>
<tr>
<td>180°C to (P_L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquidus Temperature (T_L)</td>
<td></td>
<td>217°C</td>
</tr>
<tr>
<td>Time (t_L) above (T_L)</td>
<td>80sec</td>
<td>max. 100sec</td>
</tr>
<tr>
<td>Peak Temperature (T_P)</td>
<td>245°C</td>
<td>max. 260°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>max. 250°C (power / TOLED w lens)</td>
</tr>
<tr>
<td>Time (t_P) within 5°C of the specified peak temperature (T_P - 5K)</td>
<td>20sec</td>
<td>min. 10sec max. 30sec</td>
</tr>
<tr>
<td>Ramp-Down Rate *)</td>
<td>3°C/sec</td>
<td>max. 6°C/sec maximum</td>
</tr>
<tr>
<td>(T_P) to 100°C</td>
<td></td>
<td>4°C/sec maximum (power / TOLED w lens)</td>
</tr>
<tr>
<td>Time 25 °C to Peak temperature</td>
<td></td>
<td>max. 8 min.</td>
</tr>
</tbody>
</table>

### Notes:

All temperatures refer to the center of the package, measured on the top of the component.

*) slope calculation \(\Delta T/\Delta t\): \(\Delta t\) max. 5sec; fulfillment for the whole T-range.

For superior solder joint connectivity results we recommend soldering under standard nitrogen atmosphere.
Recommendation on lead free reflow soldering

Slop Calculation

\[ \frac{\Delta T}{\Delta t} = \text{Slope} \]

with \( \Delta t = \text{max 5 sec.} \)

Calculation of slope

In Datapaq software default setting for slop calculation is 10sec

\[ \rightarrow \text{changed to 5sec} \]
Both extreme heating and cooling gradients as well as a pronounced jump in gradient or extreme long time above liquidus can cause soldering defects and/or excessive thermal stresses that lead to damage of the component.
Basic recommendations how to improve the profile:

- Limit the peak temperature to approx. 245 °C
- Linear heating
- Avoidance of jumps in gradient (transition from soak to reflow zones)
- Uniform curve progression around peak temperature in the time interval over liquidus temperature

- Use of the last heating zone for gentle cooling (approx. 170 °C)
- For active cooling zone: Increasing the operating point of the chiller (generally only possibly by equipment manufacturer)
- Cooling zones: Reduce the fan speed to minimal value
- Reduction of conveyer speed (may require simultaneous temperature adjustment \downarrow in all heating zones)
Application Notes
Home page OSRAM Opto Semiconductors

Light Emitting Diodes (LED)
- Automotive Applications
- General Lighting Applications
- LCD Backlighting Applications
- Mobile Communication
- General Information
- Measurement
- Processing and Handling
- Driving of LEDs
- Thermal Management
- Office & Computer Applications
- Intelligent Displays
- Infrared Components
- OLED
- High-Power Laser Diodes

Related Product Groups
- Automotive Applications
- General Lighting Applications
- Industry Applications
- LCD Backlighting Applications
- Mobile Communication
- Office & Computer Applications
- General Information
- Measurement
- Processing and Handling
- Driving of LEDs
- Thermal Management

Information on LED Assembly