



## Assembly Precautions for the Nichia NCSxE17x or NVSxE21x Series LEDs

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NCSxE17A, NCSxE17x, NVSxE21A, and NVSxE21x refer to Nichia part numbers. These Nichia part numbers within this document are merely Nichia’s part numbers for those Nichia products and are not related nor bear resemblance to any other company’s product that might bear a trademark.

### 1. Overview

As a result of growing trends to reduce the size and increase the light energy of LED-based luminaires, the demand for compact, high luminous flux and high efficiency LEDs has been increasing. Since Nichia's NCSxE17x/NVSxE21x (hereinafter referred to as "E17/E21 series") LEDs are smaller than other LEDs that produce the same wattage, they can expand the design flexibility for luminaires. On the other hand, the E17/E21 series LEDs require a higher degree of precision for the LED mounting techniques due to its compact package size.

This application note provides assembly and handling considerations/precautions for the E17/E21 series LEDs including the evaluation results for the LED mounting performance.

### 2. Nichia E17/E21 Series

As stated in Section 1, the E17/E21 series LEDs have a compact package and produce high luminous flux. Since the LEDs do not use a primary substrate (e.g. lead frame, etc.) for the electrical connection, the LED chip is able to be soldered directly onto a secondary substrate (i.e. a PCB); the thermal resistance can be lower. Thus, the LEDs are suitable for luminaires that require high luminous flux and high density mounting.

These LEDs may be more challenging to mount accurately on a PCB than typical LEDs due to their compact package size since their electrodes are small and close to each other, there are no solder fillets at the electrodes due to the location of the electrodes (i.e. they are located toward the center of the rear surface of the LEDs), etc.



Figure 1. Appearance of an E17/E21 Series LED

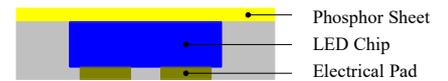
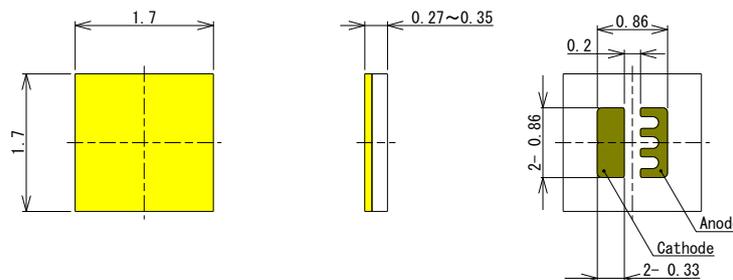
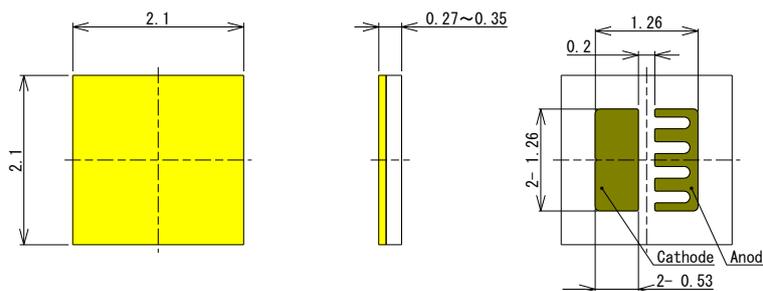


Figure 2. Structure of the E17/E21 Series LEDs



(Unit: mm)

Figure 3. Outline Dimensions of the NCSxE17x LED



(Unit: mm)

Figure 4. Outline Dimensions of the NVSxE21x LED

For the E17/E21 series LEDs, the dimensions of the electrodes are different depending on the product version. See the applicable specifications for details.

- NCSxE17A: 0.86mm, NCSxE17A-V1: 0.84mm
- NVSxE21A: 1.26mm, NVSxE21A-V1: 1.24mm

### 3. Handling Precautions

Since the package of the E17/E21 series LEDs is thin and has no submount, it is more sensitive to external stress/pressure applied to the LEDs than typical LEDs. Additionally, note that an ESD protection device (e.g. Zener diode) is not incorporated in the E17/E21 series LEDs. Necessary measures should be taken to protect the LEDs from external stress/pressure and ESD damage.

#### 3.1 Placement Pressure During the Pick-and-place Process

When the LEDs are picked up by a pick-and-place nozzle, the placement pressure must not exceed 5N. The recommended mounting conditions, including a recommended nozzle configuration, are provided in Section 6.

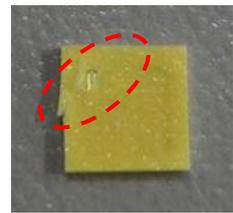


Figure 5. Example of an LED Damaged by Excessive Pressure

#### 3.2 Handling with Bare Hands

The LEDs should not be handled with bare hands. This may contaminate the resin and have an effect on the optical characteristics. Also, it may cause damage to the resin (e.g. cut, scratch, chip, crack, etc.), deformation of the LED, etc. causing a catastrophic failure (i.e. the LED not to illuminate). In addition, the LED chip may become damaged due to ESD since a protection device is not incorporated in the LEDs.

#### 3.3 Handling with Tweezers

The LEDs should not be handled with tweezers. The resin of the sides of the LEDs is very soft; if pressure is applied to the resin while handling the LEDs with tweezers, that may cause the same damage/effect on the LEDs as handling them with bare hands (i.e. damage to the resin, a catastrophic failure, etc.).

#### 3.4 Stacking Assembled PCBs Together

Since the resin used in the LEDs is soft, do not stack assembled PCBs together. Otherwise, it may cause damage to the resin (e.g. cut, scratch, chip, crack, delamination and deformation) and the internal connection to fail causing a catastrophic failure. This also should be taken into consideration when packing assembled PCBs into a container for transportation.

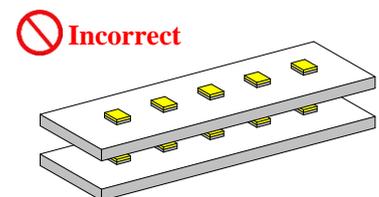


Figure 6. Stacked Assembled PCBs

### 3.5 Hand Soldering

Do not perform hand soldering. Since the electrodes of the LEDs are located toward the center on the rear surface of the package, soldering with a soldering iron is not feasible. Also, using a hot plate may result in failures (e.g. an open/short circuit) since the electrode positions cannot be visually confirmed from above.

### 3.6 Repair/Rework

Taking into consideration what is described in section 3.5, do not repair/rework the soldering area after soldering. Do not manually place the LEDs onto a PCB even for reflow soldering since it may cause failures (e.g. an open/short circuit).

### 3.7 Electrostatic Discharge (ESD)

#### 3.7.1. Measures Against ESD

LEDs are sensitive to transient excessive voltages (e.g. ESD, lightning surge). If this excessive voltage occurs in the circuit, it may cause the LEDs to be damaged causing issues (e.g. the LEDs to become dimmer or not to illuminate [i.e. catastrophic failure]).

Ensure that when handling the LEDs, necessary measures are taken to protect them from an ESD discharge. The following examples are recommended measures to eliminate the charge:

- Grounded wrist strap, ESD footwear, clothes, and floors
- Grounded workstation equipment and tools
- ESD table/shelf mat made of conductive materials

Ensure that all necessary measures are taken to prevent the LEDs from being exposed to transient excessive voltages (e.g. ESD, lightning surge):

- tools, jigs, and machines that are used are properly grounded
- appropriate ESD materials/equipment are used in the work area
- the system/assembly is designed to provide ESD protection for the LEDs

Table 1 provides an example ESD checklist for reference purposes.

Table 1. ESD Checklist (Example)

| Target    | Check Item  | Check Method Example          |
|-----------|---|-------------------------------|
| Operator  | Is the operator wearing a grounded wrist strap?   | Resistance Measurement        |
|           | Is the wrist strap properly in contact with the operator's skin?                                | Resistance Measurement        |
|           | Is the operator wearing antistatic clothes?   | Resistance Measurement        |
|           | Is the operator wearing conductive footwear?  | Resistance Measurement        |
| Workbench | Is the workbench equipped with a conductive mat on the top surface?                             | Surface Potential Measurement |
|           | Is the top surface of the workbench grounded with a resistance of approximately 1MΩ?            | Resistance Measurement        |
|           | If a power supply will be used, is it properly insulated from the top surface of the workbench? | -                             |

|                   |  |                                    |
|-------------------|--|------------------------------------|
|                   | Are there no tools, equipment, etc. that can become charged easily (e.g. a tool made of plastic) near the workbench?                       | -                                  |
| Work Area         | Are the machines/equipment that are installed in the work area properly grounded?<br>Are the tools, cushion of the chair, etc. antistatic? | Resistance Measurement             |
|                   | Are the insulated surfaces of the equipment, etc. uncharged in the area where high-pressure air is used?                                   | Surface Potential Measurement      |
|                   | Is the ionizer that is used to neutralize electrostatic charges properly inspected?  | Surface Potential Measurement      |
|                   | Are metal and/or charged objects kept away from the components that are sensitive to static electricity during all processes?              | -                                  |
|                   | Is the floor conductive?<br>Is the floor properly maintained?  | Resistance Measurement             |
|                   | Are temperature and humidity controlled?   | Temperature & Humidity Measurement |
| Packing Materials | Will static electricity not occur due to friction between the packing materials and the contents?  | Surface Potential Measurement      |
|                   | If an antistatic coated magazine rack is reused, will a coating be reapplied to it?  | -                                  |
|                   | Is the cushioning antistatic?  | -                                  |

### 3.7.2 Measures for when the Tool/Equipment Used is an Insulator

If the tool/equipment used is an insulator (e.g. glass cover, plastic, etc.), ensure that necessary measures have been taken to protect the LEDs from transient excessive voltages (e.g. ESD). The following examples are recommended measures to eliminate the charge:

- Dissipating static charge with conductive materials
- Preventing charge generation with moisture
- Neutralizing the charge with ionizers

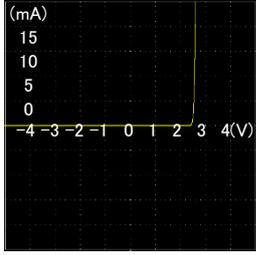
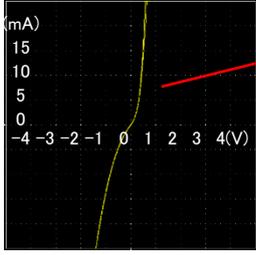
### 3.7.3 Identifying ESD Damaged LEDs

To identify if an LED was damaged by transient excess voltages (i.e. an ESD event during the system's assembly process), perform a characteristics inspection (e.g. forward voltage measurement, light-up test) at low current (a forward current of  $\leq 1\text{mA}$  is recommended). If the LED was damaged by transient excess voltages (e.g. ESD), it would cause the Forward Voltage ( $V_F$ ) to decrease, the LED not to illuminate at a low current, etc.

For the failure criteria for the LEDs, refer to the applicable specification; the failure criteria for the  $V_F$  at the forward current of 0.5mA is specified.

For reference purposes, Table 2 provides an example of the waveform of an ESD damaged LED.

Table 2. Example of the Waveform of an ESD Damaged LED

|                               | Normal LED  | ESD Damaged LED  |
|-------------------------------|---|--|
| Forward Current Applied       | 0.5mA   | 0.5mA  |
| Forward Voltage               | 2.48V   | 0.22V  |
| $V_F$ - $I_F$ Characteristics |  |  |

Short Circuit

### 3.7.4 ESD Protection for LEDs

To protect PCB assemblies with the LEDs from ESD, mounting Zener diode(s) on the PCB will be effective. For reference purposes, Nichia provides precautions/considerations for selecting/mounting Zener diode(s):

- Ensure that the voltage of the Zener diode(s) is higher than the  $V_F$  of the LEDs in the whole operating temperature range for the LEDs. When selecting Zener diode(s), especially take variations in the voltage and/or the temperature characteristics of each individual Zener diode into consideration.
- Ensure that the Zener diode(s) are mounted sufficiently close to the LEDs. Note that the distance between the LEDs and Zener diode(s) are not shown in a circuit diagram; ensure that the actual distance is appropriate.
- Ensure that ESD current will be bypassed through the Zener diode(s); when selecting the location(s) to mount the Zener diode(s), it is necessary to identify the areas on the PCB where static charges are likely to occur (e.g. the areas where an operator may touch) in order to create an effective flow path for the ESD current. See Figure 7.

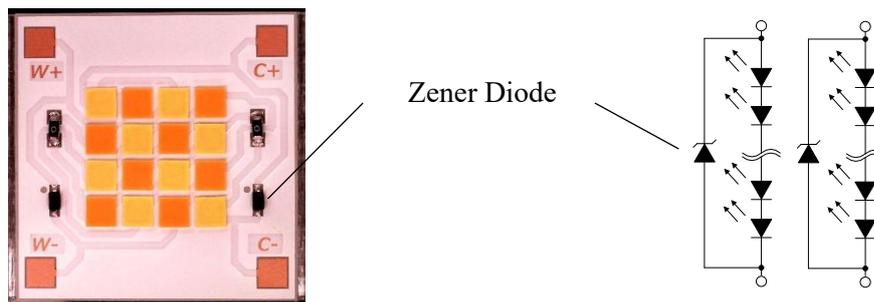


Figure 7. Example of a PCB with the LEDs and Zener Diodes

### 4. Cautions/Recommendations for LED Mounting

Design/precision of the soldering pad pattern and the metal solder stencil aperture greatly affect the mounting accuracy of the E17/E21 series LEDs since their electrodes are small and the clearance between the anode and cathode terminals is narrow. The design and material of the PCB are also important for the heat dissipation of the LEDs. This section provides cautions/recommendations for LED mounting conditions showing the results of the evaluations Nichia performed.

#### 4.1 Recommended Soldering Pad Pattern and Metal Solder Stencil Aperture

Table 3. Recommended Soldering Pad Pattern and Metal Solder Stencil Aperture for the NCSxE17x LEDs

| NCSxE17x                                |  |                               |
|---|--|-------------------------------|
| LED                                     | Soldering Pad Pattern and Solder Mask Aperture | Metal Solder Stencil Aperture |
|   |  |                               |
| Metal Solder Stencil Thicknesses: 100μm |  |                               |

- Soldering Pad Pattern
- Solder Mask Aperture
- Metal Solder Stencil Aperture

Table 4. Recommended Soldering Pad Pattern and Metal Solder Stencil Aperture for the NVSxE21x LEDs

| NVSxE21x                                |  |                               |
|---|--|-------------------------------|
| LED                                     | Soldering Pad Pattern and Solder Mask Aperture | Metal Solder Stencil Aperture |
|   |  |                               |
| Metal Solder Stencil Thicknesses: 100μm |  |                               |

- Soldering Pad Pattern
- Solder Mask Aperture
- Metal Solder Stencil Aperture

## 4.2 PCB Materials

In general, glass epoxy substrates (FR4), glass composite substrates (CEM3), and metal-core substrates (aluminum substrates, etc.) are widely used as PCBs to attach LEDs. Nichia recommends using a metal-core PCB when the E17/E21 series LEDs are being used for a high-density application since it has high thermal conductivity and good heat dissipation performance. Refer to the application note “NxSxExxA Design Considerations for Direct Mountable Chip LEDs for High-Density Applications” for the relationship between the thickness of the PCB and heat dissipation performance.

## 4.3 Insulation Layer

The thickness and material of the insulation layer for the PCB greatly affect the heat dissipation performance of the LEDs. Use a PCB with a suitable insulation layer for the thermal design of the chosen application. Refer to the application note “Thermal Design Considerations for the Nichia NCSWE13x, NCSxE17x, or NVSxE21x Series LEDs” for the relationship between the insulating layer and heat dissipation performance.

## 4.4 Copper Layer

Nichia recommends a thickness of 35 $\mu$ m for the copper layer of the soldering pad pattern. Note that when typical etching techniques are used to create the soldering pad pattern, the thicker the copper layer is, the less precise the etching becomes. Since the electrodes of the E17/E21 series LEDs are very small and close to each other (i.e. the clearance between the electrode pads is as narrow as 200 $\mu$ m), mounting failures may occur, resulting in an open/short circuit if the soldering pad pattern is not created accurately.

## 4.5 Copper Layer Design

There are two types of copper layer designs: Non-Solder Mask Defined (NSMD) and Solder Mask Defined (SMD). As shown in Table 5, both structures have advantages and disadvantages. Considering that high mounting accuracy is required for the E17/E21 series LEDs, Nichia recommends NSMD; generally, NSMD can create a soldering pad pattern that is more precise in size and shape than SMD since the copper layer allows for better control of the dimensional tolerances than the solder resist. The heat dissipation performance is better with SMD since the copper layer around the LED can be larger. However, if the coating accuracy of the solder resist is poor, the shape and location of the soldering pad pattern can differ from the intended design dimensions (it may have effects on the placement accuracy).

Table 5. Copper Layer Design Comparison (NSMD vs. SMD)

| Soering Pad Pattern | NSMD  | SMD  |
|---------------------|---|--|
| Reference Diagram   |   |  |
| Solder Balls/Voids  | <p>Advantage:<br/>Occurrence of solder balls/voids is reduced.</p>  |  |
| Placement Accuracy  | <p>Advantage:<br/>The coating accuracy of the solder resist does not have as much of an effect on the placement accuracy.</p> | <p>Disadvantage:<br/>The coating accuracy of the solder resist effects the placement accuracy.</p> |
| Heat Dissipation    | <p>Disadvantage:<br/>Limited heat dissipation performance due to a small copper layer area.</p>                               | <p>Advantage:<br/>Good heat dissipation performance due to a large copper layer area.</p>          |

### 4.6 Metal Solder Stencil Aperture

Since the metal solder stencil apertures for the E17/E21 series LEDs are very small, they may become clogged with solder paste during the solder printing process depending on the method for finishing the aperture surfaces. If a printing failure frequently occurs due to clogging of the metal solder stencil aperture, use a metal solder stencil whose aperture surfaces are smoother (i.e. electropolished, coated with fluorine, etc.) to ensure that the solder paste is released appropriately.



Figure 8. Example of Clogged Metal Solder Stencil Apertures

### 4.7 LED Mounting Pitch

When determining the mounting pitch between each LED for a high-density module, it is important to consider the precision of the pick-and-place machine, dimensional tolerances of the package, and tolerances between the package and electrodes. The necessary mounting pitch between each LED is shown in Equation 1 below.

Equation 1:

$$\sqrt{(\text{Precision of the machine})^2 + (\text{LED dimensional tolerances})^2 + (\text{Tolerances between the package and electrodes})^2}$$

= Unilateral tolerance  $\Rightarrow$  Bilateral tolerance  $\cong$  Mounting Pitch

$$\sqrt{0.1^2 + 0.05^2 + 0.05^2} = 0.122 \Rightarrow 0.244 \cong 0.3\text{mm}$$

If the precision of the pick-and-place machine is 0.1mm, the minimum mounting pitch obtained with Equation 1 is 0.3mm. However, since the potential for LED tilt must also be considered, a mounting pitch of  $\geq 0.4\text{mm}$  is recommended.

### 4.8 Evaluation of the Effect of Solder Volume and the Gap Between Solder Paste Deposits

Nichia evaluated the effect of solder volume for reflow-soldering the LEDs using different solder volumes (i.e. three aperture ratios for the metal solder stencil); the soldering pad patterns and metal solder stencil apertures provided in section 4.1 were used as recommended conditions (see Tables 6 and 7). NSMD structure was used for the copper layer design. The evaluation results show that there were no issues with the evaluation conditions. However, the degree of LED tilt was larger with a larger volume of solder paste.

Nichia also performed evaluations with different gaps between solder paste deposits (see Tables 8 and 9). The evaluation results show that there were no issues with the evaluation conditions. However, if the gap is too small, solder bridging may be caused by solder spread due to a low viscosity of solder paste and/or the placement pressure when placing the LEDs, resulting in a short circuit. If the gap is too large, an open circuit may occur when the LED is misaligned. Ensure that the metal solder stencil is designed to apply solder paste at the center of each electrode pad.

Table 6. Evaluation of the Effect of Solder Volume for the NCSxE17A LEDs

| NCSxE17A   |   |  |   |
|--|---|--|---|
| Solder Volume                                    | 0.2mm×0.5mm<br>(% relative to the recommendation: -17%) | 0.2mm×0.6mm<br>(Nichia's Recommendation) | 0.2mm×0.7mm<br>(% relative to the recommendation: +17%) |
| Image of Mounting Area                           |   |  |   |
| Area Ratio of the Solder Paste to Each Electrode | K: 34.5%<br>A: 50.8%                                    | K: 41.5%<br>A: 61.1%                     | K: 48.6%<br>A: 71.5%                                    |
| Solder Paste Applied                             |   |  |   |
| X-ray Image after Soldering                      |   |  |   |
| LED Tilt   |   |  |   |

Light Emitting Diode

Mounting Area

Observation Direction for the LED Tilt

- Soldering Pad Pattern
- Electrode
- Metal Solder Stencil Aperture



Table 7. Evaluation of the Effect of Solder Volume for the NVSxE21A LEDs

| NVSxE21A   |   |  |   |
|--|---|--|---|
| Solder Volume                                    | 0.35mm×0.65mm<br>(% relative to the recommendation: -19%) | 0.35mm×0.80mm<br>(Nichia's Recommendation) | 0.35mm×0.95mm<br>(% relative to the recommendation: +19%) |
| Image of Mounting Area                           |   |  |   |
| Area Ratio of the Solder Paste to Each Electrode | K: 33.6%<br>A: 52.9%                                      | K: 41.6%<br>A: 65.4%                       | K: 49.3%<br>A: 77.6%                                      |
| Solder Paste Applied                             |   |  |   |
| X-ray Image after Soldering                      |   |  |   |
| LED Tilt   |   |  |   |

Light Emitting Diode

Mounting Area

Observation Direction for the LED Tilt

- Soldering Pad Pattern
- Electrode
- Metal Solder Stencil Aperture



Table 8. Evaluation of the Effect of the Gap Between Solder Paste Deposits for the NCSxE17A LEDs

| NCSxE17A  |  |   |   |
|---|--|---|---|
| Location of the Solder Paste Deposits                   | Closer to the Inner Edge of Each Electrode Pad | At the Center of Each Electrode Pad<br><i>(Nichia's Recommendation)</i> | Closer to the Outer Edge of Each Electrode Pads |
| Image of Mounting Area and Solder Paste Applied<br><br> |  |   |   |
|   |  |   |   |
| X-ray Image after Soldering                             |  |   |   |
| LED Emission  | No Issue                                       | No Issue  | No Issue  |
| Solder Ball   | None   | None  | None  |

Table 9. Evaluation of the Effect of the Gap Between Solder Paste Deposits for the NVSxE21A LEDs

| NVSxE21A  |  |   |   |
|---|--|---|---|
| Location of the Solder Paste Deposits                   | Closer to the Inner Edge of Each Electrode Pad | At the Center of Each Electrode Pad<br><i>(Nichia's Recommendation)</i> | Closer to the Outer Edge of Each Electrode Pads |
| Image of Mounting Area and Solder Paste Applied<br><br> |  |   |   |
|   |  |   |   |
| X-ray Image after Soldering                             |  |   |   |
| LED Emission  | No Issue                                       | No Issue  | No Issue  |
| Solder Ball   | None   | None  | None  |

### 4.9 Evaluation of Self-alignment Performance

Nichia evaluated the self-alignment performance of the reflow-soldered LEDs with the evaluation conditions used to evaluate the effect of solder volume as detailed in section 4.8. NSMD structure was also used for the copper layer design for this evaluation.

As shown in the evaluation results provided in Figures 9 to 16, the larger the solder volume was, the better the self-alignment performance was. Considering that the evaluation results provided in section 4.8 show that the degree of LED tilt was larger with a larger volume of solder paste, there is a tradeoff between the self-alignment performance and the LED tilt.

Table 10. Evaluation Conditions for the Self-alignment Performance for the NCSxE17A LEDs

|   |                        |                        |                |                |
|---|------------------------|------------------------|----------------|----------------|
| Image of Mounting Area and Solder Paste Applied |                        |                        |                |                |
| LED Placement Position                          | x: +0.1mm<br>y: +0.1mm | x: -0.1mm<br>y: -0.1mm | $\theta$ : +2° | $\theta$ : +5° |
|   |                        |                        |                |                |

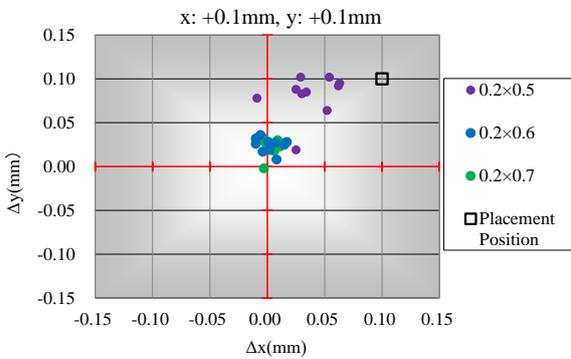


Figure 9. Evaluation Results for the NCSxE17A LEDs (x: +0.1mm, y: +0.1mm)

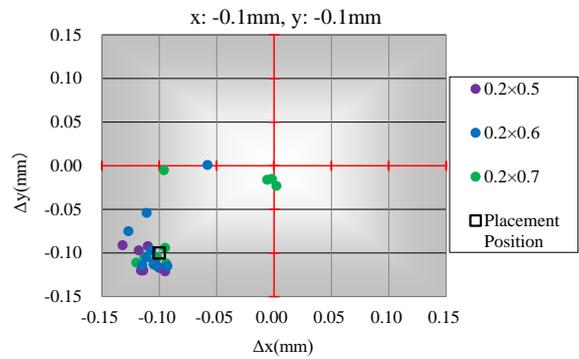


Figure 10. Evaluation Results for the NCSxE17A LEDs (x: -0.1mm, y: -0.1mm)

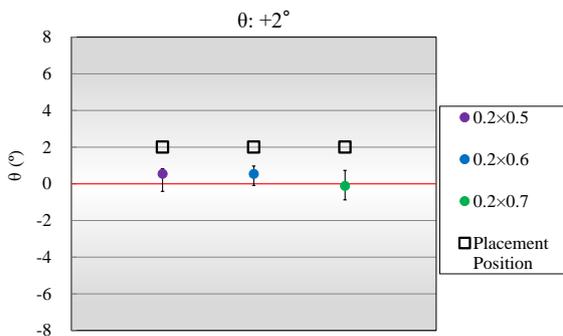


Figure 11. Evaluation Results for the NCSxE17A LEDs ( $\theta$ : +2°)

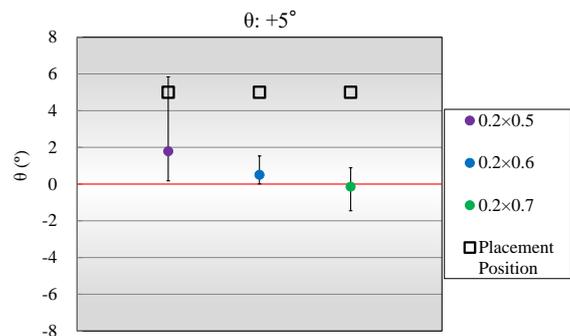
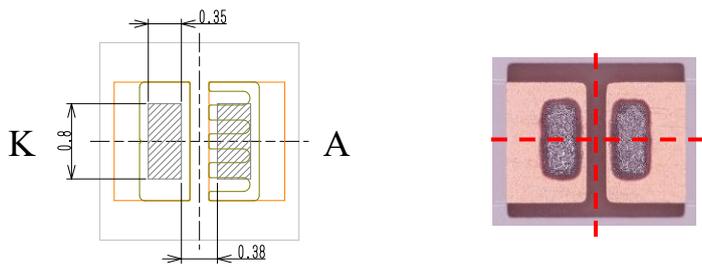
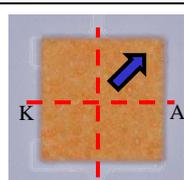
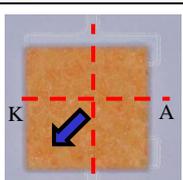
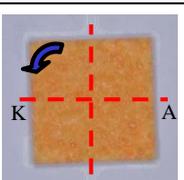
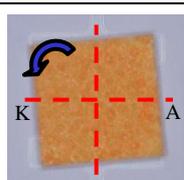


Figure 12. Evaluation Results for the NCSxE17A LEDs ( $\theta$ : +5°)

Table 11. Evaluation Conditions for the Self-alignment Performance for the NVSxE21A LEDs

|   |  |  |  |   |
|---|--|--|--|---|
| Image of Mounting Area and Solder Paste Applied |                                |  |  |   |
| LED Placement Position                          | <p>x: +0.1mm<br/>y: +0.1mm</p>  | <p>x: -0.1mm<br/>y: -0.1mm</p>  | <p><math>\theta</math>: +2°</p>  | <p><math>\theta</math>: +5°</p>  |

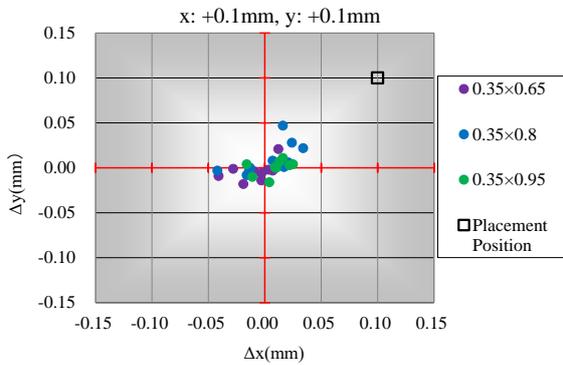


Figure 13. Evaluation Results for the NVSxE21A LEDs (x: +0.1mm, y: +0.1mm)

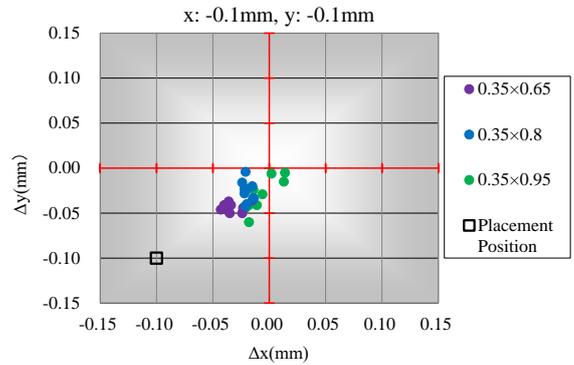


Figure 14. Evaluation Results for the NVSxE21A LEDs (x: -0.1mm, y: -0.1mm)

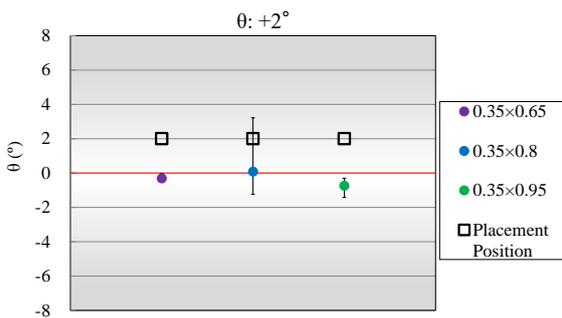


Figure 15. Evaluation Results for the NVSxE21A LEDs ( $\theta$ : +2°)

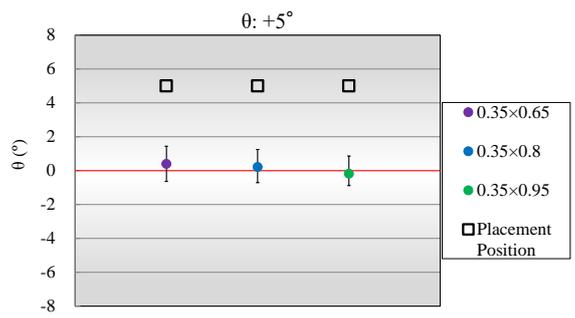


Figure 16. Evaluation Results for the NVSxE21A LEDs ( $\theta$ : +5°)

### 5. Solder Printing Process

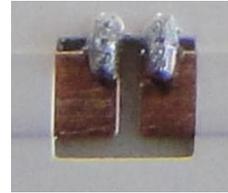
For the E17/E21 series LEDs, if solder printing is not performed appropriately, mounting failures (e.g. an open/short circuit) may occur since the electrodes are small and close to each other. A high degree of precision in solder printing is required for these LEDs.

 **Incorrect**



This May Result in a Short Circuit.

 **Incorrect**



This May Result in an Open Circuit.

Figure 17. Examples of Incorrect Solder Printing

#### 5.1 Solder Paste

Considering solder printability, Nichia recommends using solder paste with a particle size of  $\leq 30\mu\text{m}$ . Generally, an appropriate particle size for a given metal solder stencil is approximately one-fifth of the aperture width and at most one-third of the stencil thickness. If the particle size is too large, that may result in an insufficient amount of solder paste filling since the gaps between solder particles are wider and/or a larger amount of solder paste is removed by the squeegee. If the particle size is too small, that may result in issues such as solder balls, decreased solder wettability, etc. since the total surface area of the solder paste increases, leading to more surface oxidation.

Regarding solder composition, Nichia recommends SAC solder (Sn-3.0Ag-0.5Cu) or silver-free solder (e.g. SN100C manufactured by Nihon Superior Co., Ltd.). If high reliability solder paste is used in order to increase the bonding strength, stress caused by temperature fluctuations may be transferred to the LED chips leading to cracks/damage to them since the solder joint is less likely to absorb the stress.

Depending on the type/composition of the solder paste, the reliability of the LEDs may be affected; verifications must be performed using the chosen solder paste to ensure that there are no issues with the mounting performance and the reliability of the LEDs.

#### 5.2 Squeegee

Common materials for squeegees include urethane, metal, etc. If a soft squeegee (e.g. a urethane squeegee) is used, its tip may become deformed at the aperture of the metal solder stencil causing the solder to be scraped off from unintended areas, resulting in an insufficient amount of solder paste filling.

Since the E17/E21 series LEDs require highly precise solder printing, using a squeegee with good solder deposition performance (e.g. a metal squeegee) is recommended. Note that a metal squeegee causes greater wear on the metal solder stencil compared to a urethane squeegee.

Taking into consideration the possible misaligned solder printing position, the PCB and the metal solder stencil must be designed to ensure that the printing direction (i.e. the travel direction of the squeegee) is perpendicular to the long side of the metal solder stencil apertures for the LED

electrodes (i.e. the row of the electrode pads) as shown in Figure 18. If the printing direction is parallel or angled relative to the long side of the apertures and if the solder printing position is misaligned due to manufacturing variations of the PCB/metal solder stencil, that may result in an electrical connection failure caused by an open/short circuit.

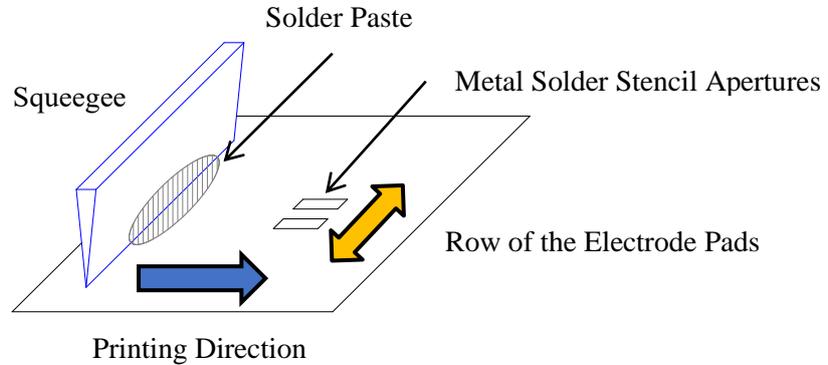


Figure 18. Solder Printing Direction

### 5.3 Printing Speed

Most solder printing machines allow the printing speed (i.e. the travel speed of the squeegee) to be adjusted in the printing condition settings (see Figure 19). If the speed is too high, the solder paste may not be adequately supplied to the metal solder stencil apertures (e.g. solder skipping), resulting in insufficient amount of solder paste filling. To prevent this, reduce the printing speed so that the solder paste rolls in accordance with the squeegee movement.

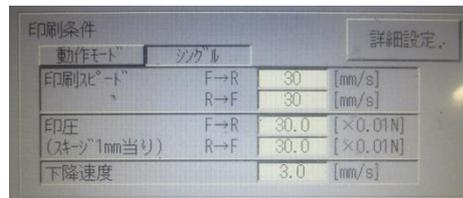


Figure 19. Reference Image of the Condition Setting Screen

### 5.4 Pressing Pressure of the Squeegee

In addition to the printing speed, the pressing pressure of the squeegee can be adjusted in the printing condition settings. If the pressing pressure is too low, the squeegee may not adequately wipe away excess solder paste resulting in excessive amount of solder filling. If the pressing pressure is too high, the squeegee may remove the solder paste excessively resulting in an insufficient amount of solder filling, and/or the squeegee/metal solder stencil may become worn more quickly leading to a shorter service life for those items. As a general rule, set the pressing pressure as low as possible while ensuring that the amount of solder paste filling is not excessive. Since the solder printing performance changes depending on the type/conditions of the solder paste, squeegee, etc., ensure that the solder printing conditions are checked as needed (e.g. per production lot, per shift, etc.).

### 5.5 Inspection During the Solder Printing Process

To quantitatively inspect the solder printing performance, use a solder paste printer that is capable of three-dimensional measurement. Since the solder printing area is small for the E17/E21 series LEDs, ensure that the selected printer has an adequate measurement accuracy. See Table 12 and Figure 20 for more examples of possible solder printing failures other than the ones described above.

Table 12. Additional Examples of Failures that May Occur During the Solder Printing Process

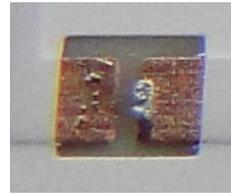
| Failure  | Cause  | Preventive Measures   |
|--|--|---|
| Solder Bleeding Outside the Metal Solder Stencil Apertures | Gap between the metal solder stencil and PCB is too large. | <ul style="list-style-type: none"> <li>• Modify the installation height of the metal solder stencil and/or the PCB holding method.</li> </ul>   |
| Solder Skipping  | The metal solder stencil aperture is clogged.              | <ul style="list-style-type: none"> <li>• Clean the apertures regularly.</li> <li>• Use a metal solder stencil whose aperture surfaces are processed to allow a good solder paste release.</li> </ul>            |
|  | The solder paste is dry.                                   | <ul style="list-style-type: none"> <li>• Review the mixing conditions for solder paste.</li> <li>• Establish appropriate usage conditions for solder paste (i.e. number of prints and elapsed time).</li> </ul> |

**Incorrect**



Solder Bleeding

**Incorrect**



Solder Skipping

Figure 20. Examples of Soldering Printing Failures

## 6. Precautions for Setting Up a Pick-and-Place Machine/Nozzle

This section provides precautions for setting up a pick-and-place machine and a pick-and-place nozzle. Placement accuracy is also required for the E17/E21 series LEDs as well as solder printing accuracy since their package size is small.

### 6.1 Types of Tape Feeder

There are two types of tape feeder: an electrical (motorized) feeder and a mechanical (pneumatic) feeder. Generally, an electrical feeder creates less vibration during the tape feeding, leading to more stable component feeding. If pick-up errors occur when the LEDs are picked up (e.g. the LEDs are picked up in a tilted position, the LEDs fall out of the embossed carrier tape pocket, etc.), reduce the feed speed of the tape feeder or use an electrical feeder with a low feed vibration.

Additionally, if the feed vibration is high, the LEDs may contact the feeder cover between the removal of the top cover tape and LED suction, causing damage to the LED surface. This may also be prevented by reducing the feed speed, using an electrical feeder, and/or by removing the top cover tape just before LED suction.

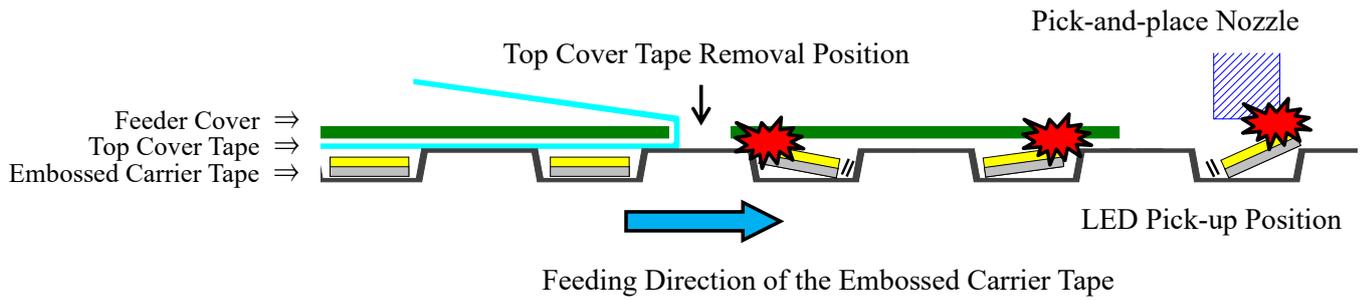


Figure 21. Examples of LED Pick-up Failures

### 6.2 Pick-and-place Nozzle

Use an appropriate nozzle for the outline dimensions of the package of the E17/E21 series LEDs. If an inappropriate nozzle is used, pick-up failures may occur (e.g. air leak at the time of LED suction, a tilted suction of the LEDs, damage to the LED surface, etc.), causing the performance of the LEDs to be affected (e.g. reduction in brightness, color shift, etc.). Pick-and-place nozzles for 1005 or 1608 package components may be appropriate for the LEDs. However, since it may vary depending on the pick-and-place machine, sufficient verification should be performed to ensure there are no issues with the nozzle being used.

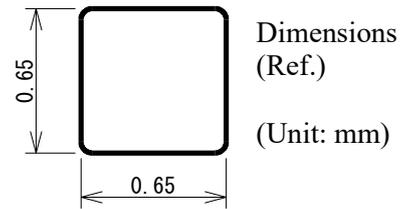


Figure 22. Example of Recommended Nozzle Dimensions

### 6.3 Imaging-based Automatic Inspection

For accurate placement of the LEDs, use an automatic imaging-based recognition technology to correct misalignments for each LED. To improve the placement accuracy, Nichia recommends using the electrodes as a reference for location/positioning purposes.

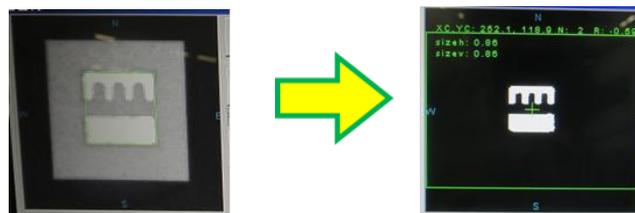


Figure 23. Reference Images for Detection of the Electrodes and Misalignment Correction

### 6.4 Recommended Nozzle Height for Pick-up Operations

Nichia recommends the nozzle goes down only to the height of the edge of the embossed carrier tape pocket to pick up the LEDs. If the pick point of the nozzle is too high, it may cause insufficient suction power leading to picking errors (e.g. the nozzle's failure to pick/lift the LEDs into the air, incorrect picking causing the LEDs to tilt when in the air). If the pick point of the nozzle is too low, it may cause damage to the LED surface, cause the embossed carrier tape to deform leading to a picking failure, etc. The reference height may vary depending on the pick-and-place machine; compare the reference height of the pick-and-place machine being used to the actual nozzle height and make adjustments as necessary.

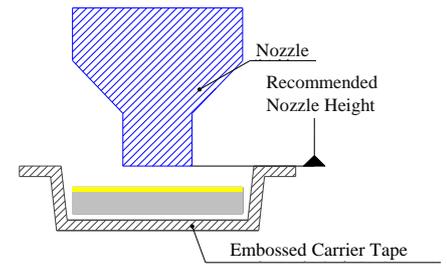


Figure 24. Recommended Nozzle Height for Pick-up Operations Dimensions

### 6.5 Recommended Nozzle Height for Placement Operations (Placement Depth)

Nichia recommends that the nozzle further presses the LEDs 0.2mm onto the PCB from the height where the LEDs first touch the solder paste. If the placement depth of the nozzle is insufficient, the LEDs may not be released from the nozzle after placement or may float after reflow. If the placement depth is too large, that may cause the LED surface to be damaged and/or the excess solder paste to be extruded around the LED package resulting in formation of solder balls.

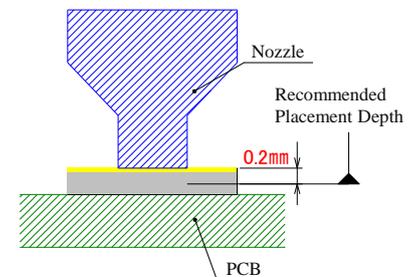


Figure 25. Recommended Nozzle Height for Placement (Placement Depth)

### 6.6 Inspection After LED Placement

Nichia recommends performing an inspection after electrical components, including the LEDs, are placed on the PCB (i.e. before reflow) either visually or using an automatic imaging inspection system to check if all necessary components are properly placed. See Table 13 for more examples of possible LED placement failures other than the ones described above.

Table 13. Additional Examples of Failures that May Occur During the LED Pick-up/Placement Process

| Failure   | Cause  | Preventive Measures  |
|---|--|--|
| Pick-up Error   | The nozzle position to pick up the LEDs is inappropriate.  | <ul style="list-style-type: none"> <li>Adjust the pick-up position to ensure that the center of the nozzle and the center of the LED surface are aligned.</li> </ul> |
| Placement Error (The LEDs stick to the nozzle after placement.) | The solder amount is too small.  | <ul style="list-style-type: none"> <li>Modify the solder printing conditions.</li> </ul>   |
|   | The PCB is bent/warped. The PCB thickness has been set incorrectly in the pick-and-place machine.                                  | <ul style="list-style-type: none"> <li>Use a PCB holder that provides full-surface support for the PCB.</li> <li>Correct the setting.</li> </ul>                     |
| Misaligned Placement Position                                   | The coordinates of the reference marks on the metal solder stencil/PCB are not programmed correctly in the pick-and-place machine. | <ul style="list-style-type: none"> <li>Correct the program.</li> </ul>   |
|   | The manufacturing accuracy for the PCB is not sufficient.  | <ul style="list-style-type: none"> <li>Change the copper layer design method for the soldering pad pattern, solder resist, etc.</li> </ul>                           |

### 7. Reflow Process

The recommended reflow soldering conditions are shown in Table 14.

If conditions other than those noted in Table 14 would be applied, then it should be based on the recommended conditions of the chosen solder paste. Air flow soldering conditions can cause optical degradation, caused by heat and/or atmosphere. Nitrogen reflow soldering is recommended.

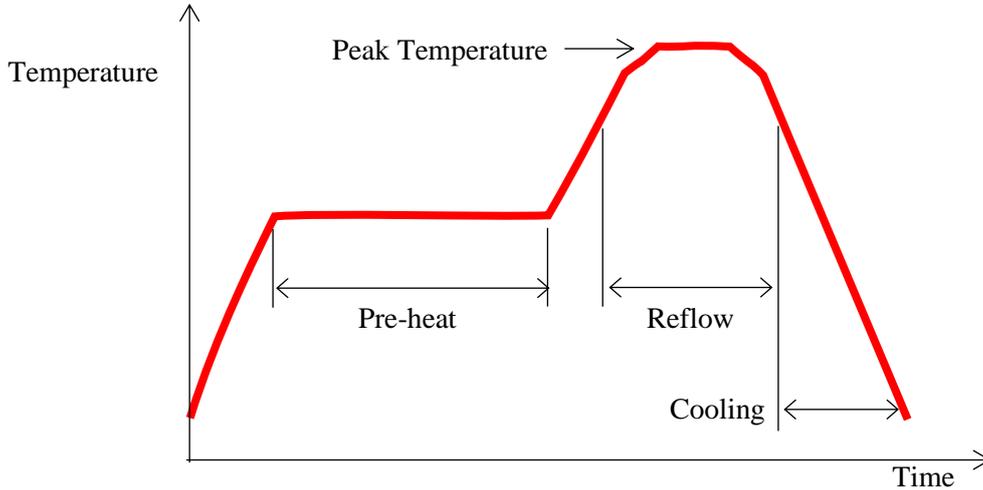


Figure 26. Reflow Profile

Table 14. Recommended Reflow Conditions for the E17/E21 Series LEDs

| Item/Zone  | Recommended Conditions                             | Note   |
|--|--|--|
| Heating Speed:<br>• Start to Pre-heat Zone<br>• Pre-heat Zone to Reflow Zone | 1-5°C/sec  | A faster heating speed increases the potential occurrence of solder balls and/or the solder paste to slump (e.g. too much heat and the solder paste is too thin [low viscosity]).  |
| Pre-heat Zone  | Temp.: 180-200°C<br>Time: 90 <sup>1</sup> -120 sec | The solvent in the paste begins to evaporate. If the pre-heat time is too short, it increases the potential occurrence of poor solder wettability and solder voids. If the pre-heat time is too long, the activation period of the flux decreases and unmelted solder is more likely to occur. |
| Reflow Zone  | Temp.: 220-260°C<br>Time: 30 <sup>1</sup> -60 sec  | The temperature is kept above the melting point of the solder.<br>If the temperature is not high enough and if the reflow time is not long enough, it may lead to soldering failures (e.g. unmelted solder).   |
| Peak Temperature   | Temp.: <260°C<br>Time: <10 sec                     | If the temperature is too high, it may result in an increase in the potential occurrence of flux deterioration and/or solder ball formation. The temperature must not exceed the heat-resistant temperatures of the LEDs and the other electrical components on the PCB.                       |
| Cooling Speed  | - <sup>1</sup>                                     | Do not cool the LEDs rapidly; note that if the cooling speed is too slow, that may decrease the solder joint strength.   |

<sup>1</sup> Use the conditions recommended for the solder paste being used.

## 8. Inspection after Reflow

Since the E17/E21 series LEDs are small and the electrical pads are hidden on the back side of the LEDs, the accuracy of the soldering conditions is not able to be confirmed during the reflow process, so an inspection after the reflow process is important. The inspection criteria need to be determined depending on the user's chosen assembly process and application. The inspection process below describes what items need to be checked for solderability. Evaluation tests such as reliability tests are needed to ensure the reliability of LED mounted PCBs or fixtures.

### 8.1 Lighting Inspection

Visual inspection by eyes or using an image inspection machine to verify if the LEDs are lit normally.

### 8.2 Electrical Characteristics Inspection

Inspection of the electrical characteristics to determine if the forward current is being applied as designed, whether the forward voltage value is reasonable in relation to the applied forward current, etc.

### 8.3 Visual Inspection

A visual inspection by eyes or using an image inspection machine to inspect that the LEDs are mounted properly (e.g. no misalignment, lifting, solder ball, LED damage). Since the E17/E21 series LEDs are small and the electrical pads are hidden on the back side of the LEDs, a visual inspection may not be able to detect soldering failures.

### 8.4 X-ray Inspection

An X-ray inspection is used for inspecting the solder wettability, for solder voids, and for solder balls.

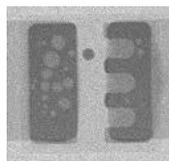


Figure 27. Example of a Solder Ball



Figure 28. Example of Poor Wettability

## 9. Summary

The E17/E21 series LEDs require more caution regarding the assembly techniques than typical LED packages since the structure of the electrodes of the E17/E21 series LEDs is nonstandard. As a result, the PCB design for the E17/E21 series LEDs is important.

If the accuracy of the PCB design is poor, assembly failures may continue to occur even if the assembly process is reviewed and improved. A receiving inspection of the PCB must be performed to ensure that PCBs are made as designed.

Although this application note explains precautions and failure modes during the assembly process, the user is still responsible for evaluating the chosen assembly process and reliability.

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