



Design Considerations for the Nichia NFSWL11A-D6 LED

Light Emitting Diode

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The Nichia part numbers NFSWL11A-D6 and NFSW757H-V1 within this document are merely Nichia 's part numbers for the Nichia products and are not related nor bear resemblance to any other company' s product that might bear a trademark.

1. Overview

In recent years, a lighting segment called Task-Ambient has received more attention. Compared to traditional luminaires, whose light is often too intense and feels bright, Task-Ambient luminaires provide soft illumination evenly to the whole space while ensuring appropriately high illuminance for certain areas where specific activities are performed. It helps to create a comfortable atmosphere. To respond to consumers' needs, Nichia has added LEDs with a wide directivity that can be used for ambient lighting to the portfolio for general lighting; the NFSWL11A-D6 LED is one of them. This application note provides information on directions for appropriate use and design considerations for the NFSWL11A-D6 LED.

2. Outline Dimensions and Directivity

2.1 Structure and Outline Dimensions

Figure 1 shows the appearance and outline dimensions of the NFSWL11A-D6 LED.

This LED has a diffusion layer on the phosphor layer. The structure enables the light to be emitted from all surfaces of the diffusion layer (i.e. five sides) to achieve a wide-angle light distribution.

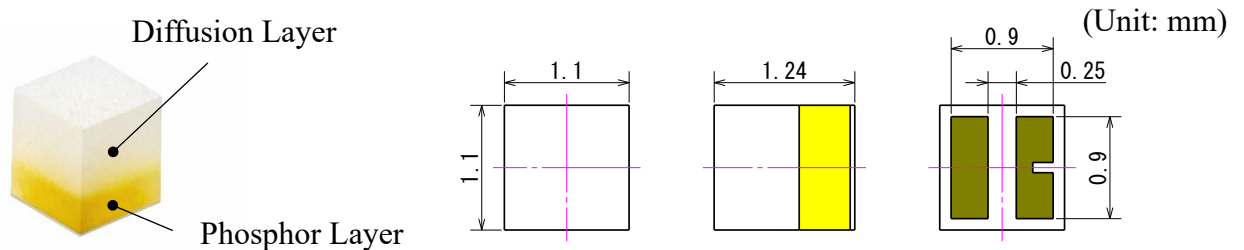


Figure 1. Appearance and Outline Dimensions of the NFSWL11A-D6 LED

2.2 Directivity

Table 1 shows a comparison of the directivity between a typical LED (i.e. the directivity is not wide) and the NFSWL11A-D6 LED.

Table 1. Comparison of the Directivity

	Directivity of a Typical LED	Directivity of the NFSWL11A-D6 LED
Directivity		
Details	• Angle of half intensity: 120° • These LEDs can be used for various types of applications by controlling the light distribution using a secondary optical lens or reflector.	• Angle of half intensity: >180° • These LEDs can create luminaires with reduced glare since the light is distributed in the horizontal direction due to the LED structure (i.e. the light is emitted from five sides).

Nichia performed evaluations on the luminaires using the NFSWL11A-D6 LEDs for various design and use conditions; the results are provided in the following sections.

3. Evaluation for How the Emitting Surfaces of a Luminaire Look

With the NFSWL11A-D6 LED (wide directivity), luminaires that emit light through a diffusion cover (e.g. a flat ceiling luminaire) can be designed to be low-profile with a uniform luminance on its emitting surfaces (i.e. the top and side surfaces).

This section provides the results of the evaluation for how the emitting surfaces look when the directivity of the LED and the LED pitches vary using two types of LEDs with different directivity characteristics.

3.1 Evaluation Method

Nichia prepared two types of LEDs with different directivity characteristics for the evaluation: the NFSWL11A-D6 LED (wide directivity) and the NFSW757H-V1 LED (typical directivity). These LEDs were mounted on PCBs with different LED pitches, with each PCB containing only one type of LED. Using a diffusion cover shown in Figure 2, Nichia evaluated how the top and side surfaces of the diffusion cover (i.e. the emitting surfaces of a luminaire) look when the LEDs are operated. See Tables 2 and 3 for the details of the PCBs and the diffusion cover used for the evaluation.

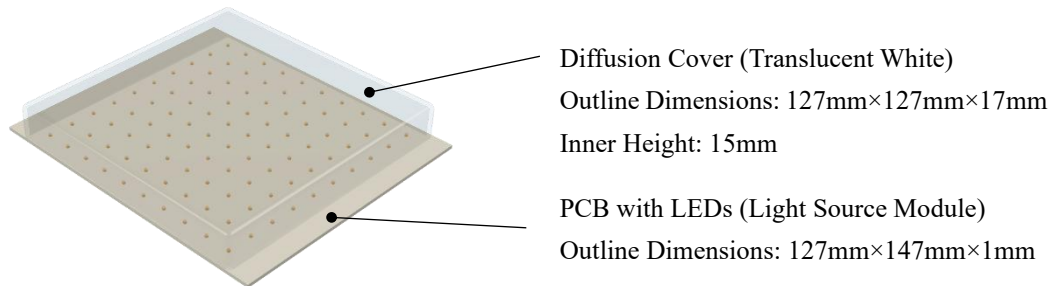


Figure 2. Appearance and Outline Dimensions of the Evaluated PCB and Diffusion Cover

Table 2. Details of the the Evaluated Light Source Modules

	10mm	15mm	20mm	25mm
LED: NFSWL11A-D6				
LED: NFSW757H-V1				
# of LEDs Mounted	144	64	36	25

Table 3. Detailed Information for the Evaluated PCB and Diffusion Cover

Item	Details
PCB	PCB: FR4, copper layer thickness of 35μm, substrate thickness of 1mm Solder resist: High-reflective white solder resist (PSR-4000 LEW7S manufactured by TAIYO HOLDINGS CO., LTD.)
Diffusion Cover	Acrylic diffusion cover (Sumipex™ 040 Opal, 2mm thickness, manufactured by Sumika Acryl Co., Ltd), Total light transmission: 52.1%

3.2 Evaluation Results

Table 4 shows the results of the evaluation for how the emitting surfaces look and of the optical simulation for the luminance distribution on those surfaces.

Table 4. Results of the Evaluation and Optical Simulation

Evaluated LED	Evaluated Item	LED Pitch (mm)			
		10	15	20	25
NFSWL11A-D6	Top Surface of Diffusion Cover				
	Side Surface of Diffusion Cover				
	Luminance Distribution on Top Surface				
	Luminance Distribution on Side Surface				
	Luminance Uniformity	Uniform	Uniform	Uniform	Not Uniform (Grainy)
NFSW757H-V1	Top Surface of Diffusion Cover				
	Side Surface of Diffusion Cover				
	Luminance Distribution on Top Surface				
	Luminance Distribution on Side Surface				
	Luminance Uniformity	Uniform	Not Uniform (Grainy)	Not Uniform (Grainy)	Not Uniform (Grainy)

The evaluation results confirm that compared to the LED with a typical directivity, the wide directivity LED achieves a uniform luminance on both the top and side surfaces of the diffusion cover with fewer LEDs. It also confirmed that the wide directivity LED provided a lower luminance on the emitting surfaces to reduce glare when both of the evaluated LEDs were operated with the same amount of current.

The optical simulation showed results comparable to the sensory evaluation (i.e. the visual evaluation for the surfaces of the diffusion cover); the slight non-uniformity of the color and dark spots were not reproduced by the simulation. When designing a luminaire, ensure that a sensory evaluation is performed with the chosen luminaire.

4. Evaluation Using Different Distances between the PCB and Diffusion Cover

When LEDs with a typical directivity are used in a luminaire with a diffusion cover (e.g. flat ceiling luminaire), to reduce the grainy look of the emitting surfaces and provide a more uniform luminance, the optical distance (i.e. distance between the PCB surface and the inner surface of the diffusion cover, hereinafter referred to OD) needs to be equal to or larger than the LED pitch. In comparison, with the wide directivity LED, it is possible to obtain a uniform luminance with a smaller OD. This section provides results of the evaluation for how the emitting surfaces look when the LED pitch and OD varies using two types of LEDs with different directivity characteristics.

4.1 Evaluation Method

Nichia prepared two types of LEDs with different directivity characteristics for the evaluation: the NFSWL11A-D6 LED (wide directivity) and the NFSW757H-V1 LED (typical directivity). These LEDs were mounted on PCBs with different LED pitches, with each PCB containing only one type of LED. Spacing frames with different heights (i.e. each height represents each evaluation OD) were prepared; they were placed between the PCB and diffusion cover to create each target OD. Using the equipment as shown in Figure 3, Nichia evaluated how the top surface of the diffusion cover looks when the LEDs are operated. See Table 5 for the details of the LEDs, PCB, and diffusion cover used for the evaluation.

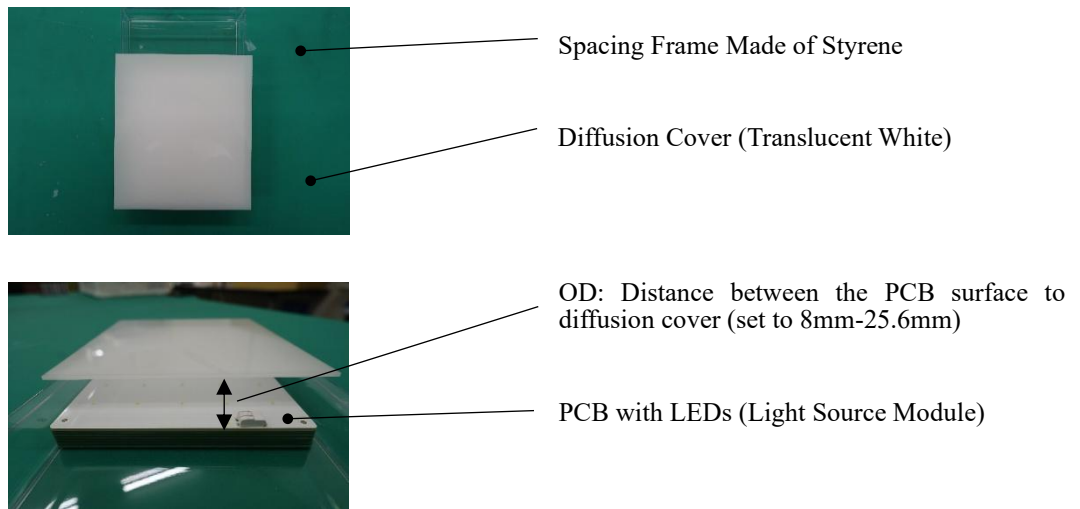


Figure 3. Equipment Used for the Evaluation

Table 5. Detailed Information for the Evaluated LEDs, PCB, and Diffusion Cover

Item	Details
LED	The NFSWL11A-D6 LEDs, Color rank: sm503R8000 The NFSW757H-V1 LEDs, Color rank: sm503R8000
PCB	PCB: FR4, copper layer thickness of 35 μ m, substrate thickness of 1mm Solder resist: High-reflective white solder resist (PSR-4000 LEW7S manufactured by TAIYO HOLDINGS CO., LTD.)
Diffusion Cover	Acrylic diffusion cover (Sumipex™ 040 Opal, 2mm thickness, manufactured by Sumika Acryl Co., Ltd) Total light transmission: 52.1%

4.2 Evaluation Results

Tables 6 and 7 show the results of the evaluation for how the emitting surface looks.

Table 6. Evaluation Results for the Wide Directivity LED (i.e. NFSWL11A-D6)

		Approximate Optical Distance (mm)											
		25.6	24	22.4	20.8	19.2	17.6	16	14.4	12.8	11.2	9.6	8.0
LED Pitch (mm)	10												
	OD/P	○ (2.56)	○ (2.40)	○ (2.24)	○ (2.08)	○ (1.92)	○ (1.76)	○ (1.60)	○ (1.44)	△ (1.28)	△ (1.12)	△ (0.96)	○ (0.80)
	15												
	OD/P	○ (1.71)	○ (1.60)	△ (1.49)	△ (1.39)	△ (1.28)	△ (1.17)	△ (1.07)	△ (0.96)	△ (0.85)	○ (0.75)	× (0.64)	× (0.53)
	20												
	OD/P	△ (1.28)	△ (1.20)	△ (1.12)	△ (1.04)	△ (0.96)	△ (0.88)	△ (0.80)	○ (0.72)	× (0.64)	× (0.56)	× (0.48)	
	25												
	OD/P	△ (1.02)	△ (0.96)	△ (0.90)	△ (0.83)	○ (0.77)	○ (0.70)	× (0.64)	× (0.58)	× (0.51)			

○: Uniform, △: Mostly Uniform (Dark Lines), ×: Not Uniform (Grainy)

The evaluation results confirm that the best OD for each LED pitch evaluated are as follows for the wide directivity LED: 8mm OD for a 10mm pitch, 11.2mm OD for a 15mm pitch, 14.4mm OD for a 20mm pitch, and 17.6 mm OD for a 25mm pitch. The ODs are approximate values due to potential inaccuracies with the measurement conditions.

The dark lines mentioned in Table 6 occur due to the directivity characteristics of the wide directivity LED; see Figure 4.

A dark line may be created by this area.

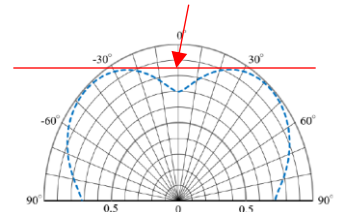


Figure 4. Directivity Characteristics of the Wide Directivity LED

Table 7. Evaluation Results for an LED with a Typical Directivity (i.e. NFSW757H-V1)

		Approximate Optical Distance (mm)											
		25.6	24	22.4	20.8	19.2	17.6	16	14.4	12.8	11.2	9.6	8.0
LED Pitch (mm)	10												
	OD/P	○ (2.56)	○ (2.40)	○ (2.24)	○ (2.08)	○ (1.92)	○ (1.76)	○ (1.60)	○ (1.44)	○ (1.28)	△ (1.12)	× (0.96)	× (0.80)
	15												
	OD/P	○ (1.71)	○ (1.60)	○ (1.49)	○ (1.39)	△ (1.28)	△ (1.17)	× (1.07)	× (0.96)	× (0.85)	× (0.75)	× (0.64)	× (0.53)
	20												
	OD/P	△ (1.28)	△ (1.20)	△ (1.12)	× (1.04)	× (0.96)	× (0.88)	× (0.80)	× (0.72)	× (0.64)	× (0.56)	× (0.48)	
	25												
	OD/P	× (1.02)	× (0.96)	× (0.90)	× (0.83)	× (0.77)	× (0.70)	× (0.64)	× (0.58)	× (0.51)			

○: Uniform, △: Mostly Uniform, ×: Not Uniform (Grainy)

The evaluation results confirm that the best OD for each LED pitch evaluated are as follows for the typical directivity LED:

12.8mm OD for a 10mm pitch and 20.8mm OD for a 15mm pitch.

The ODs are approximate values due to potential inaccuracies with the measurement conditions.

In Figures 5 and 6 below, the evaluation results in Tables 6 and 7 are provided graphically.

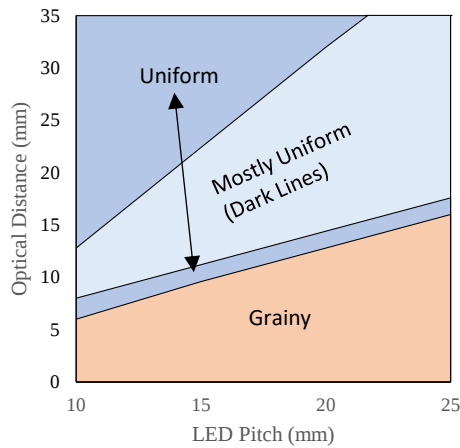


Figure 5. Graphical Image of How the Emitting Surface Looks for the Wide Directivity LED

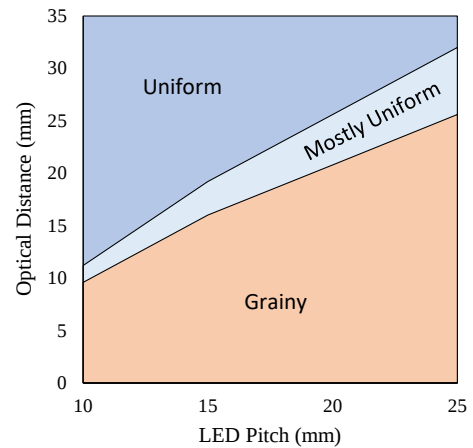


Figure 6. Graphical Image of How the Emitting Surface Looks for the Typical Directivity LED

The evaluation results confirm that the distance between the PCB surface to the diffusion cover can be shorter with the wide directivity LED than with the typical directivity LED; it is suggested that the wide directivity LED is a better choice to design a low-profile luminaire. See Figure 7.

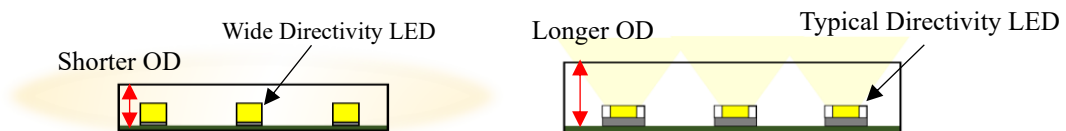


Figure 7. Luminaire Height (i.e. Optical Distance)

According to the evaluation results, the values of the OD/Pitch (i.e. optical distance divided by LED pitch) with which acceptable results were obtained are at least ~0.7-0.8 for the wide directivity LED. It may vary depending on the material and/or specifications of the diffusion cover; ensure that evaluation is performed using the final luminaire. For reference, Nichia provides information for other diffusion covers Nichia evaluated and obtained equivalent results to the evaluation described above; the results are not provided in this application note.

Table 8. Detailed Information for the Extra Diffusion Covers Evaluated

Diffusion Cover #	Details
1	Polycarbonate opaque plate that is weather-resistant on both sides (PCSP677T manufactured by C.I. TAKIRON Corporation) Thickness: 2mm Total light transmission: 42%
2	Polycarbonate opal plate that is weather-resistant on both sides (ECD3031UU manufactured by Sumitomo Bakelite Co., Ltd.) Thickness: 2mm Total light transmission: 37%

5. Considerations for Selecting a PCB

5.1 Beam Angle Comparison between the Wide Directivity LED and a Typical Directivity LED

For the wide directivity LED, light emitted from the LED hits the PCB and/or solder resist and it may cause the PCB/solder resist to discolor, crack, etc. around the soldering pad pattern. See Figures 8-10.

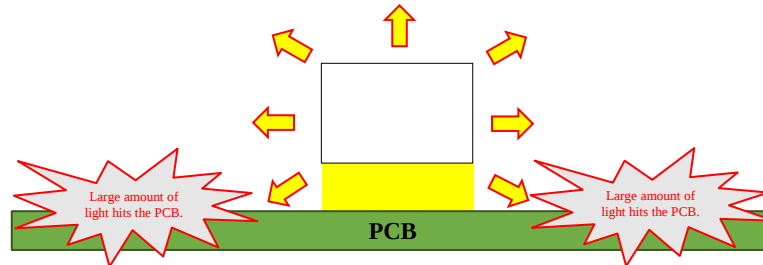


Figure 8. How the Light Emitted from the Wide Directivity LED Hits the PCB/Solder Resist

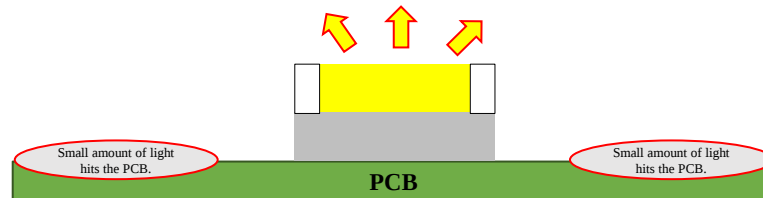


Figure 9. How the Light Emitted from a Typical Directivity LED Hits the PCB/Solder Resist

For reference, Figure 10 shows the diagrams of the light distribution of the PCBs on which the wide directivity LEDs or typical directivity LEDs are mounted (i.e. light source modules). Based on the diagrams, a PCB receives more light from the light source module with wide directivity LEDs than from the light source module with typical directivity LEDs.

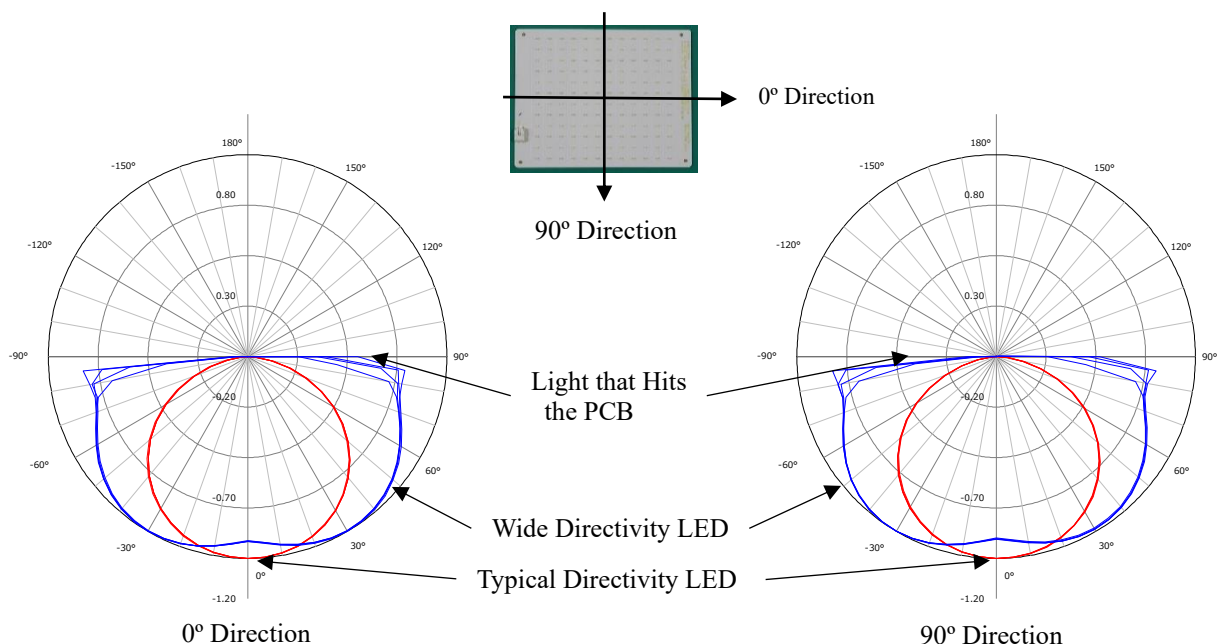


Figure 10. Light Distribution Characteristics of the Light Source Modules

5.2 Reliability Tests for the Light Source Modules

Nichia performed operating life tests at room temperature, high temperature, as well as high temperature and high humidity for the light source modules to evaluate how the light emitted from the LEDs affects the PCB and/or solder resist around the soldering pad pattern. The test conditions and results are provided in the following sections.

5.2.1 Evaluated Light Source Modules

Table 9 provides detailed information of the evaluated light source modules. Figure 11 shows the copper layer designs used for the evaluation.

Table 9. Details of the Evaluated Light Source Modules

Module #	LED	PCB Type	Solder Resist	Copper Layer Design
1	NFSWL11A-D6	Flexible	Coverlay (i.e. No Solder Resist)	NSMD
2	NFSWL11A-D6	CEM3	Alkaline Developable (High-reflective)	NSMD
3	NFSWL11A-D6	CEM3	UV Curable	NSMD
4	NFSWL11A-D6	CEM3	Alkaline Developable (High-reflective)	SMD

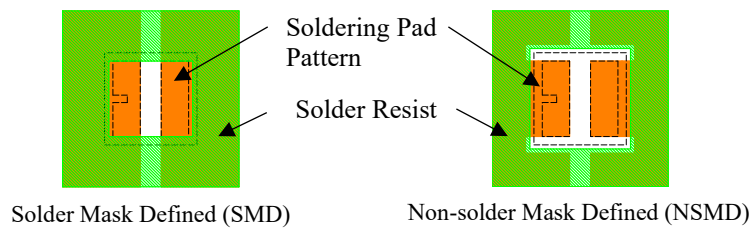


Figure 11. Copper Layer Designs to Create the Soldering Pad Pattern

5.2.2 Evaluation Results

Tables 10-13 show the evaluation results for Modules 1-4 shown in Table 9 respectively.

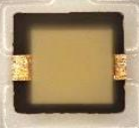
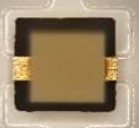
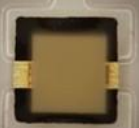
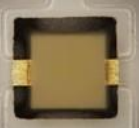
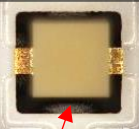
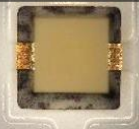
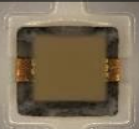
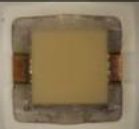
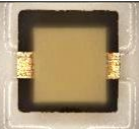
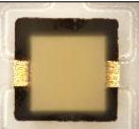
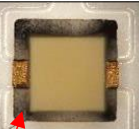
Table 10. Evaluation Results for Module 1 (Flexible PCB, NSMD)

Test Duration	0h	300h	500h	1000h	2000h	3000h
Test Item						
Room Temperature Operating Life 25°C, I _F =250mA						
Result	No Abnormality	No Abnormality	No Abnormality	No Abnormality	Discolored Coverlay	Discolored Coverlay
High Temperature Operating Life 100°C, I _F =250mA						
Result	No Abnormality	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay
High Temperature & High Humidity Operating Life 60°C, 90%RH, I _F =300mA						
Result	No Abnormality	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay	Discolored Coverlay

The evaluation results show that when a flexible PCB was used, the coverlay became significantly discolored after approximately 300 hours of operation during the high temperature operating life as well as the high temperature and high humidity operating life tests. Discoloration of the coverlay was also eventually observed during the room temperature operating life test. The discoloration is attributed to the properties of the base material of a flexible PCB, polyimide; polyimide is prone to degrade when exposed to light while it is resistant to heat and moisture.

Based on the evaluation results, a flexible PCB must not be used for the wide directivity LEDs. If it must be used due to the design of the chosen luminaire, ensure that necessary measures are taken (e.g. using a reflective sheet, additional insulation, etc.).

Table 11. Evaluation Results for Module 2
(CEM3 PCB with Alkaline Developable Solder Resist, NSMD)

Test Duration Test Item	0h	300h	500h	1000h	2000h	3000h
Room Temperature Operating Life 25°C, I _F =250mA						
Result	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality
High Temperature Operating Life 100°C, I _F =250mA						
Result	No Abnormality	Discolored Base Material	Discolored Base Material	Discolored Base Material	Discolored Base Material	Discolored Base Material
High Temperature & High Humidity Operating Life 60°C, 90%RH, I _F =300mA						
Result	No Abnormality	No Abnormality	No Abnormality	Discolored Base Material	Discolored Base Material	Discolored Base Material

The evaluation results show that when the PCB used was a CEM3 PCB with alkaline developable solder resist and the NSMD structure, the base material of the PCB became discolored after approximately 300 hours of operation during the high temperature operating life test and after approximately 1000 hours of operation during the high temperature and high humidity operating life test.

Usually, discoloration of the base material of a PCB occurs as a yellowing phenomenon caused by heat; however in this evaluation, the base material became whitened due to exposure to light. Ensure that necessary measures are taken against the whitening of the PCB base material when the LEDs are used at high temperatures.

Table 12. Evaluation Results for Module 3
(CEM3 PCB with UV Curable Solder Resist, NSMD)

Test Duration	0h	300h	500h	1000h	2000h	3000h
Test Item						
Room Temperature Operating Life 25°C, $I_F=250\text{mA}$						
Result	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality
High Temperature Operating Life 100°C, $I_F=250\text{mA}$						
Result	No Abnormality	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist
High Temperature & High Humidity Operating Life 60°C, 90%RH, $I_F=300\text{mA}$						
Result	No Abnormality	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist	Discolored Solder Resist

The evaluation results show that when the PCB used was a CEM3 PCB with UV curable solder resist and the NSMD structure, the solder resist became discolored after approximately 300 hours of operation during the high temperature operating life as well as the high temperature and high humidity operating life tests. In addition, cracks were observed after approximately 2000 hours of operation. Ensure that necessary measures are taken when the LEDs are used at high temperatures.

Table 13. Evaluation Results for Module 4
(CEM3 PCB with Alkaline Developable Solder Resist, SMD)

Test Duration	0h	300h	500h	1000h	2000h	3000h
Test Item						
High Temperature Operating Life 100°C, $I_F=250\text{mA}$						
Result	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality
High Temperature & High Humidity Operating Life 60°C, 90%RH, $I_F=300\text{mA}$						
Result	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality	No Abnormality

The evaluation results show that when the PCB used was a CEM3 PCB with alkaline developable solder resist and the SMD structure, no abnormalities were observed during the high temperature operating life as well as the high temperature and high humidity operating life tests. Nichia believes it was because the SMD structure for the soldering pad pattern prevented the base material of the PCB from discoloring; since the exposed area of the base material is smaller for SMD than for NSMD, the discoloration of the base material can be reduced. In addition, discoloration of the base material and the occurrence of cracks can be minimized if the solder resist is highly reflective,

highly light-resistant, and white.

Based on the evaluation results for Modules 1-4, Nichia recommends using a rigid PCB with high-reflective, light-resistant solder resist and the SMD structure for the wide directivity LED.

6. Summary

The NFSWL11A-D6 LED is a compact LED with a wide batwing-shaped directivity. Due to its compact size and large allowable forward current, the LEDs can be used for various designs of luminaires. In this application note, Nichia provides information and precautions for when the LEDs are used in typical luminaires; refer to the information and precautions when designing a luminaire whose emitting surface should have a uniform luminance. Also, ensure that an appropriate PCB is selected for the LEDs with careful consideration of the effect of the light on the PCB and/or solder resist around the soldering pad pattern as detailed in Section 5.

The evaluation results provided in this application note were obtained under Nichia's evaluation conditions and environments. These results may vary depending on the chosen conditions and environments. Ensure that when designing a luminaire using the LEDs, sufficient evaluations are performed under the conditions/environments in which the final product (i.e. luminaire) will actually be used.

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491 Oka, Kaminaka-Cho, Anan-Shi,
TOKUSHIMA 774-8601, JAPAN

Phone: +81-884-22-2311 Fax: +81-884-21-0148