Light Emitting Diode

Design Considerations for COB Series LED-based Spotlights

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The Nichia part numbers NTCWS024B-V2, NFDWJ130B-V2, NFCLL036B, NFCLL036B-M2, NFCLL036B-M3, and NFCLL036B-M7 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

In recent years, as the number of LED-based products has increased, so too has the level of popularity that LEDs have gained as the chosen light source in a wider range of applications due to their advantages (e.g. low power consumption, long lifetime, etc.). This has encouraged many luminaire designers/manufacturers to use LEDs instead of conventional light sources (e.g. incandescent and fluorescent lamps) and enabled LED luminaires to be used everywhere in homes and offices. Spotlights are one of these luminaires facing this transition: from high-intensity discharge (HID) or halogen spotlights to LED spotlights. There is another noticeable shift in the LED spotlight industry: from SMD LED array modules to assemblies populated with a COB LED.

When used in spotlights, LEDs have specific advantages: most LEDs only emit light in the visible range. This makes them ideal for illuminating perishable, heat/UV sensitive commodities and artwork (e.g. fresh foods, frozen processed foods, clothing, drawings/paintings, photographs, etc.). Additionally, since it does not contain infrared radiation, which would cause the surface temperature of the spotlight to increase, LED spotlights may reduce the cooling load on the air conditioning system leading to cost savings.

Although SMD LEDs offered economic and environmental advantages to spotlights, SMD LED-based spotlights had challenges related to certain qualities of the light. Spotlights may be expected to play an important role in situations that require accurate color rendering, manipulation of visual appearance/texture, and event/home staging. Nichia COB LEDs will offer solutions to these issues/requirements and enable the spotlight to provide an even color and brightness without casting multiple shadows in the projected image. Additionally, they can compete with conventional light sources in terms of the quality of light as some COB LEDs feature specific color rendering indices (CRI, i.e. high CRI and special color rendering COB LEDs).

This application note details the design advantages of COB LEDs with a small light emitting surface (LES), which is a key feature of Nichia's COB LEDs, and cautions/suggestions when designing them into spotlights while also covering the basic advantages of COB LEDs and the structure of a typical LED spotlight. This application note also features Nichia's special color rendering COB LEDs intended for their respective applications showing some examples of their performances when compared to Nichia's high-efficient COB LEDs or high CRI COB LEDs.

2. Advantages of COB LEDs over SMD LEDs

Unlike SMD LEDs (i.e. generally low/middle power LEDs with a single or a few LED die in a package), COB LEDs are high power LEDs with multiple LED die on a substrate and there are functional/design-related advantages that encourage the use of COB LEDs in spotlights as detailed in Table 1 below.

Table 1. Advantages of COB LEDs vs. SMD LEDs

Advantage of COB LEDs	Note
Ease of assembly	COB LEDs are designed to be directly attached to a housing/heatsink while SMD LEDs require a PCB and soldering process in advance.
Better heat dissipation	As mentioned above, COB LEDs do not require either PCBs or soldering, resulting in a shorter thermal path and lower thermal resistance from junction to ambient.
Simplifying/reducing the size of the system design	If the chosen spotlight requires a high luminous flux, there will be more advantages to using a 10W COB LED than using multiple SMD LEDs with much lower wattages (i.e. reducing the number of components and the size of the spotlight)
Eliminating multiple shadows (i.e. similar to when illuminated by natural light)	Spotlights using multiple SMD LEDs as the light source create multiple shadows and illumination variation. This can be avoided by replacing them with a single COB LED.

3. Structure of a COB LED-based Spotlight and Key Components

Figure 1 below shows an example of the structure of a typical COB LED-based spotlight and Table 2 shows the key components and their functions.

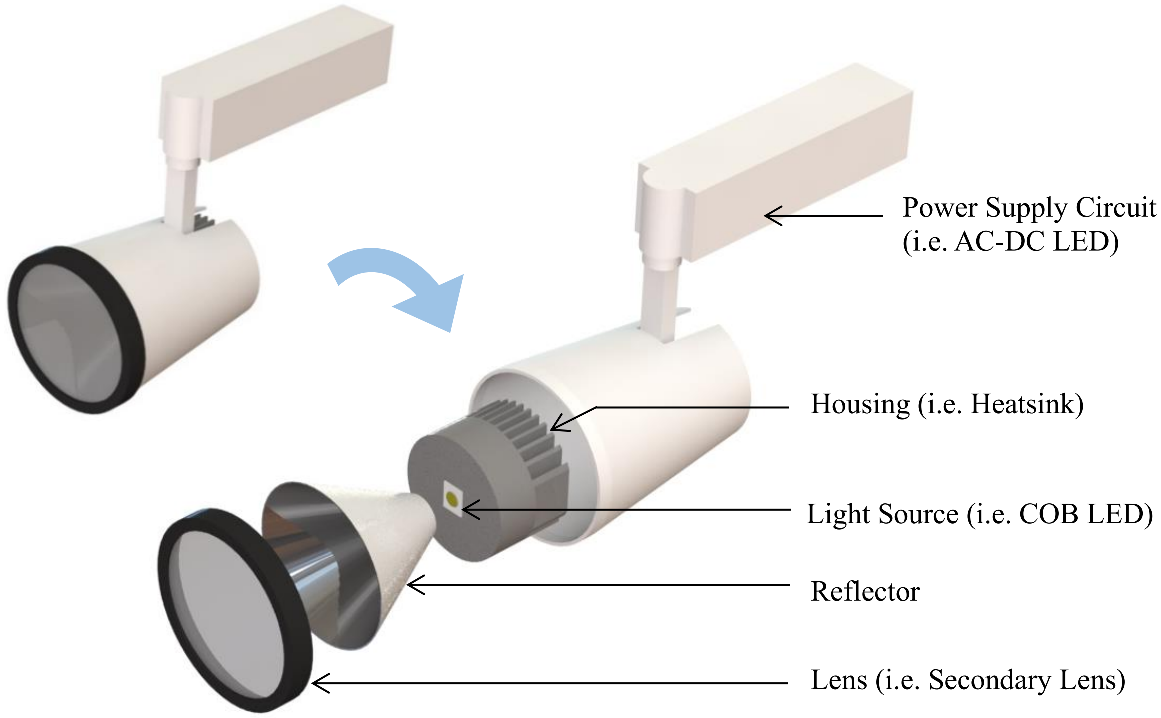


Figure 1. Structure of a typical COB-based spotlight

Table 2. Key components and their functions

Component	Function
Lens (i.e. Secondary Lens)	Refracts the light and causes it to converge/diverge to control the light distribution pattern.
Reflector	Reflects the light and directs it in an intended/designed direction for effective illumination.
Light Source (i.e. COB LED)	Determines the optical characteristics of the spotlight (i.e. luminous flux, emission color, and color rendering index)
Housing (i.e. Heatsink)	Transfers the heat generated by the COB LED to air to mitigate a reduction in the luminous flux and/or prevent a premature failure.
Power Supply Circuit (i.e. AC-DC LED Driver)	Converts the general-purpose alternating current (AC) to direct current (DC) to drive the COB LED.

4. Advantages of COB LEDs with Small Light Emitting Surfaces (LES)

The LES sizes for Nichia's COB LEDs are smaller than those of other competitors' COB LEDs and this offers the following design advantages for spotlights with narrow beam angles:

- If two spotlights have reflectors with the same size and shape, the spotlight using a COB LED with a smaller LES can produce light with a narrower beam angle.
- If the beam angle is specified, using a COB with a small LES can reduce the size of the reflector; this will be an advantage when designing a compact spotlight.

This section provides a summary of the evaluation results for the directivity/optical characteristics of the evaluation modules, and the conclusion drawn. For comparison purposes, multiple COB LEDs with different LES sizes and narrow beam reflectors with different sizes and shapes were used in the evaluation.

4.1 Test Method/Conditions

Table 3 shows the details of the four different types of COB LEDs and Table 4 shows the details of the two different types of reflectors used in the eight modules that were evaluated. The four types of COB LEDs can be divided into two sets based on the optical/electrical characteristics (i.e. "Comparison Group 1" and "Comparison Group 2" as shown in Table 3 below); the two COB LEDs from the same comparison group are designed to be operated at almost the same input power (i.e. same wattage class COB LEDs) just different sizes of LESs.

Table 3. Details of the COB LEDs used in the Evaluated Modules

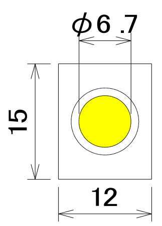
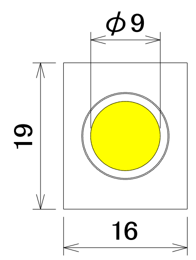
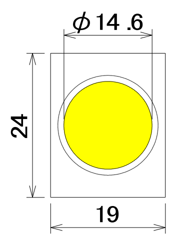
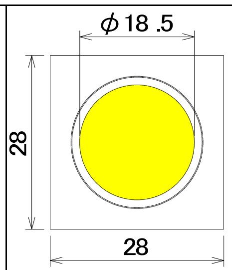
	Comparison Group 1		Comparison Group 2	
COB LED	①-S	①-L	②-S	②-L
Part Number	NTCWS024B-V2	Sample L1	NFDWJ130B-V2	Sample L2
Correlated Color Temperature, Color Rendering Index	5000K, Ra≧80		5000K, Ra≧80	
Outline Dimensions (mm)				
LES Diameter (mm)	⌀6.7	⌀9.0	⌀14.6	⌀18.5
LES Size (mm^2)	35.3	63.6	167	269
Relative Size of the LES (a.u.)	0.55	1.00	0.62	1.00
Directivity 2θ ½ (°)	118	121	116	120

Table 4. Details of the Reflectors Used in the Evaluated Modules

Reflector	A	B
Manufacturer	Nata Lighting Co., Ltd.	
Part Number	2-1120-E	4-1761-E
Outline Dimensions	Refer to Figure 3	
Appearance Overview[1]		

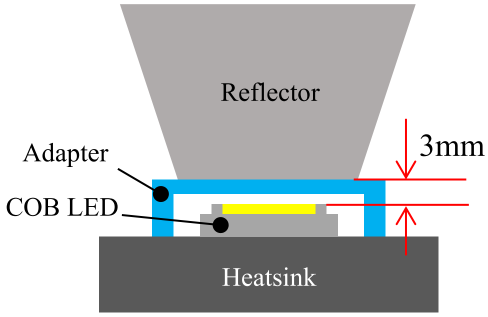


Figure 2. Structure of the evaluated module

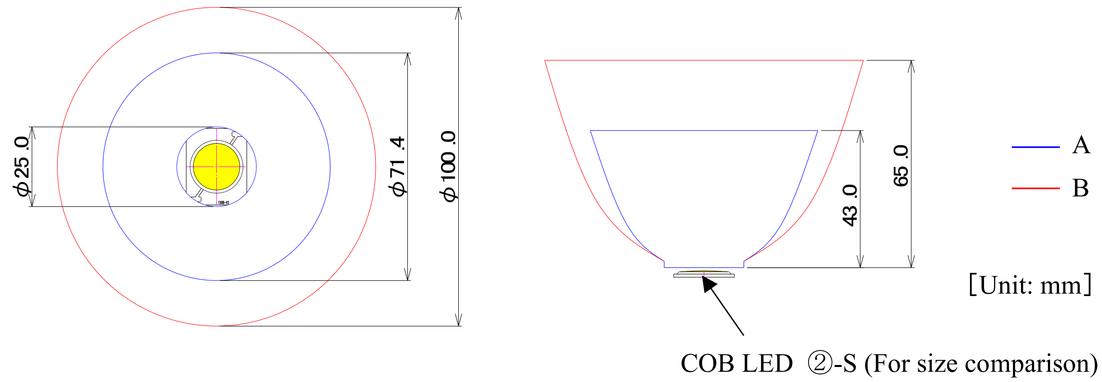


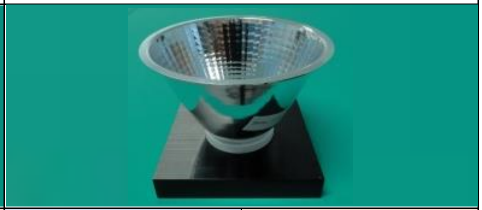
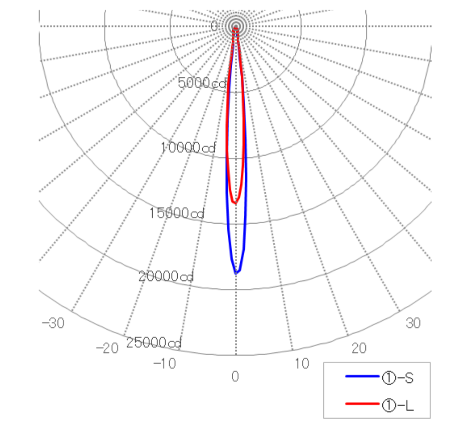
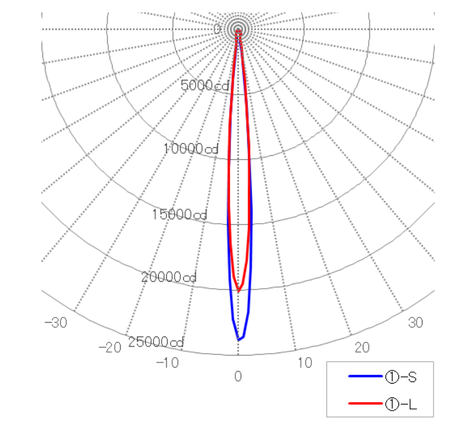
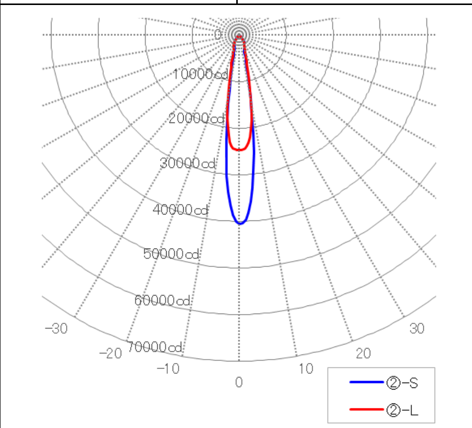
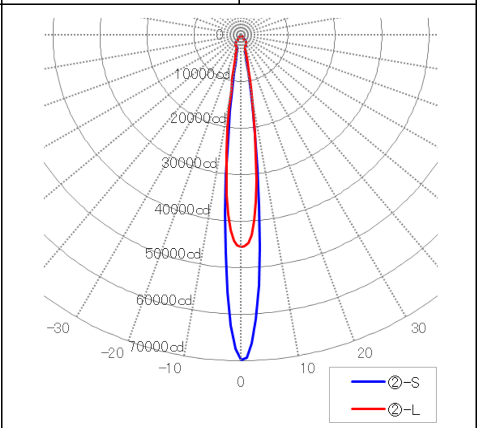
Figure 3. Outline Dimensions of the Reflectors

4.2 Comparisons between modules with the same luminous flux values

Nichia operated the evaluation modules in a manner that ensures that regardless of whether the reflector size is small (i.e. Reflector A) or large (i.e. Reflector B), their luminous flux values are the same when the COB LEDs are from the same comparison group (i.e. COB LEDs with the ID number ① or ②). The evaluation results are shown in Table 5. An important finding is that when comparing any two modules that had COB LEDs from the same comparison group and the same reflector, the module using the COB LED with a smaller LES had a higher center luminous intensity and a narrower beam angle. Using a COB LED with a small LES will improve the light collection efficacy of the spotlight and enable the spotlight to produce light with a narrow beam.

Note:
[1] The reflectors are attached to a heatsink with an adapter (See Figure 2).

Table 5. Optical measurement results of the evaluation modules when operated so that the luminous flux values are the same

Reflector	A		B	
Module Appearance Overview				
COB LED	①-S	①-L	①-S	①-L
LES Diameter (mm)	Ø6.7	Ø9.0	Ø6.7	Ø9.0
Luminous Flux (lm)	1000	1000	1000	1000
Center Luminous Intensity (cd)	18763	13428	23818	20060
Center Luminous Intensity/ Luminous Flux (cd/lm)	18.8	13.4	23.8	20.1
Directivity 2θ ½ (°)	8.3	10.0	7.4	8.3
Directivity				
COB LED	②-S	②-L	②-S	②-L
LES Diameter (mm)	Ø14.6	Ø18.5	Ø14.6	Ø18.5
Luminous Flux (lm)	6000	6000	6000	6000
Center Luminous Intensity (cd)	40498	24708	69804	45585
Center Luminous Intensity/ Luminous Flux (cd/lm)	6.7	4.1	11.6	7.6
Directivity 2θ ½ (°)	15.1	21.1	10.7	14.9
Directivity				

4.3 Comparisons between modules with the same center luminous intensity

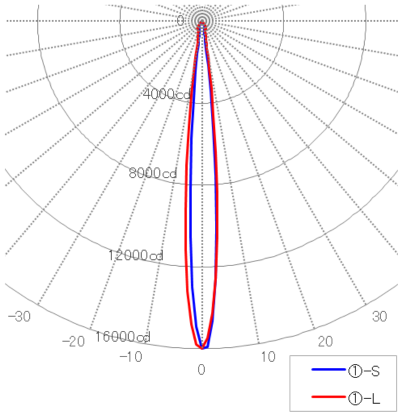
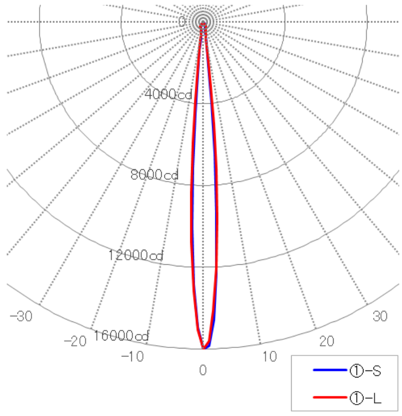
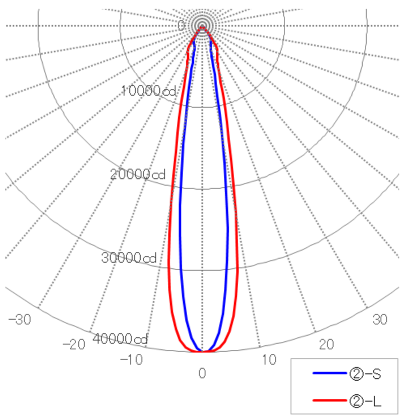
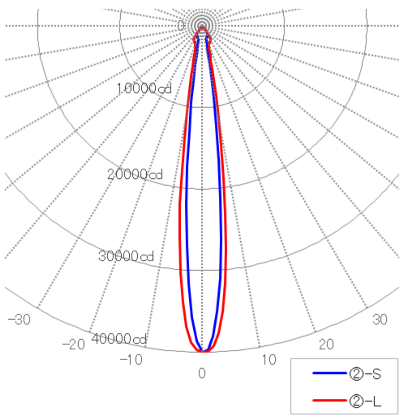
Nichia performed another similar evaluation; in this evaluation, the modules were operated in a manner that ensures that regardless of whether the reflector size is small or large, their center luminous intensity values are the same when the COB LEDs are from the same comparison group. The evaluation results are shown in Table 6. An examination of these results with a focus on the directivity values shows that:

・Comparison group 1: the module using COB LED ①-S (small LES) and Reflector A (small) and the module using COB LED ①-L (large LES) and Reflector B (large) have almost identical directivity values.

・Comparison group 2: the module using COB LED ②-S (small LES) and Reflector A (small) and the module using COB LED ②-L (large LES) and Reflector B (large) have almost identical directivity values.

These results show that when designing a spotlight, if the center luminous intensity and the directivity are specified, using a COB LED with a small LES can reduce the reflector size.

Table 6. Optical measurement results of the evaluation modules
when operated so that the center luminous intensity values are the same

Reflector	A		B	
Module Appearance Overview				
COB LED	①-S	①-L	①-S	①-L
LES Diameter (mm)	Ø6.7	Ø9.0	Ø6.7	Ø9.0
Luminous Flux (lm)	853	1192	672	797
Center Luminous Intensity (cd)	16000	16000	16000	16000
Center Luminous Intensity/ Luminous Flux (cd/lm)	18.8	13.4	23.8	20.1
Directivity 2θ ½ (°)	8.2	10.1	7.4	8.3
Directivity				
COB LED	②-S	②-L	②-S	②-L
LES Diameter (mm)	Ø14.6	Ø18.5	Ø14.6	Ø18.5
Luminous Flux (lm)	5926	9746	3443	5262
Center Luminous Intensity (cd)	40000	40000	40000	40000
Center Luminous Intensity/ Luminous Flux (cd/lm)	6.8	4.1	11.6	7.6
Directivity 2θ ½ (°)	15.1	21.2	10.8	14.9
Directivity				

Another examination of the results in Table 6 with a focus on the luminous flux values shows that:

- Both comparison groups: when the reflector sizes and shapes are the same, the COB with a smaller LES requires less luminous flux to deliver the same center luminous intensity.

This indicates that using COB LEDs with small LESs will improve the luminous efficacy of the spotlight by reducing the required luminous flux.

Figure 4 below shows the difference in the luminous efficacy between the two COB LEDs with different sizes of LESs (i.e. ①-S vs. ①-L or ②-S vs. ②-L) when assuming that the COB LEDs have the same characteristics for both the luminous flux and luminous efficacy.

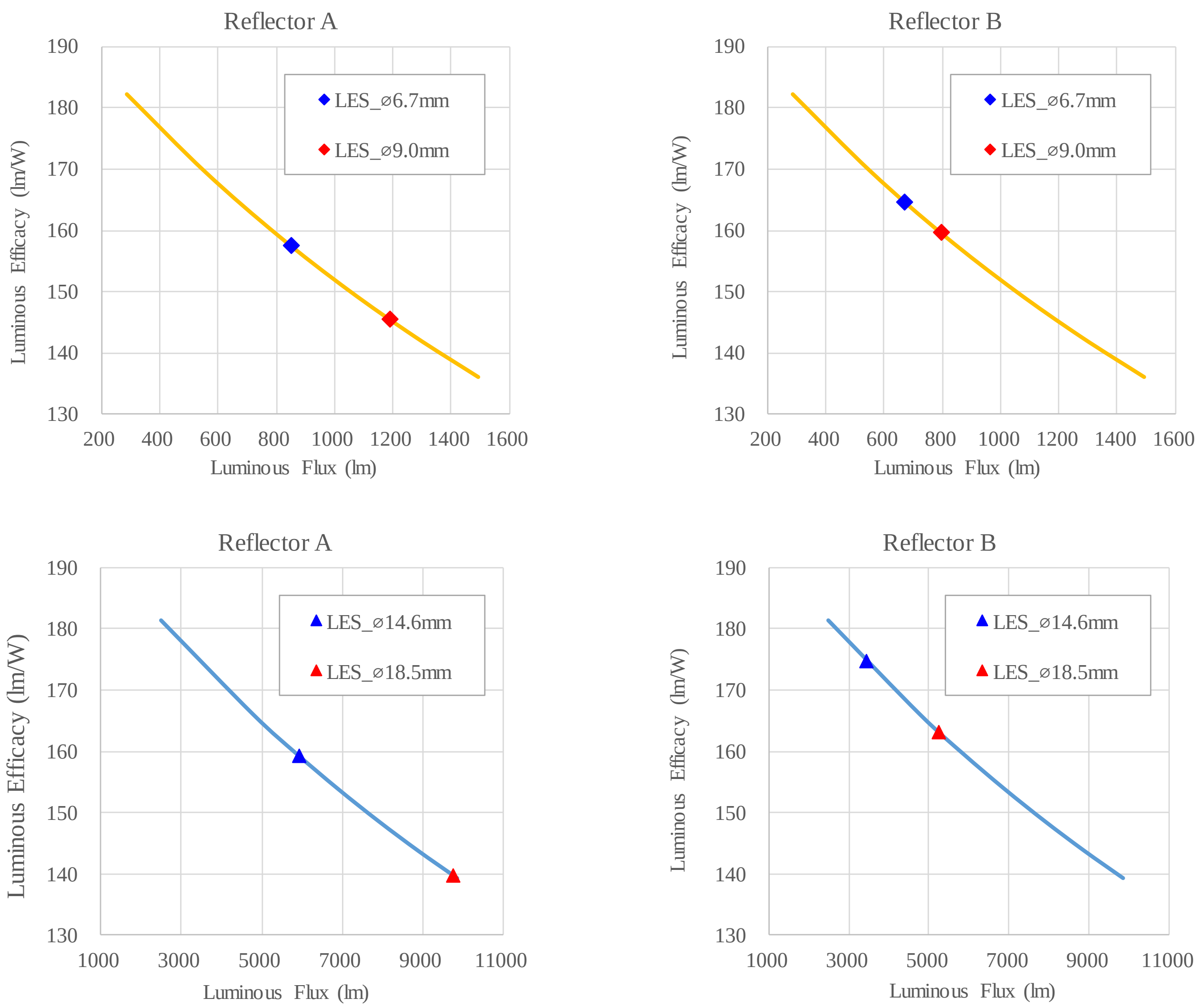


Figure 4. Advantages of COB LEDs with a small LES in increasing the luminous efficacy (lm/W) of the modules when operated so that the center luminous intensity values are the same (T_J=85°C)

5. Thermal Design Considerations to Ensure Safe Operating Junction Temperatures (T_J)

Many factors determine the actual lifetime of a COB LED; the most critical of these is the junction temperature (T_J) of the COB LED during operation. To ensure that the junction temperature (T_J) is sufficiently low, it is very important to optimize the thermal management of the COB LED. Additionally, when determining the dielectric strength between the COB LED live parts and housing/heatsink, it should be considered how the chosen design may affect the COB LED junction temperature (T_J).

This section provides precautions when designing/manufacturing an LED spotlight using Nichia's COB LEDs to prevent failures due to an increase in the COB LED junction temperature (T_J).

5.1 Attaching a COB LED to a housing/heatsink

To increase the adhesion strength between the COB LED and housing/heatsink for better heat dissipation, Nichia recommends using a specially designed COB LED holder with a thermal interface material (TIM), especially thermal grease. However, there are two important points to be aware of when using holders:

・Depending on the TIM (e.g. thermal conductivity, thickness, etc.), the heat dissipation varies; sufficient verification should be performed to determine the proper TIM for the chosen application.

・Typically, COB LED holders are designed to be attached to housings/heatsinks with screws. The adhesion strength between the COB LED holder and housing/heatsink (i.e. heat dissipation) can greatly vary depending on the tightening torque. However, if the tightening torque is too high, it may cause the COB LED ceramic substrate to be damaged. Refer to the product documentation of the selected COB LED holder for the torque specifications and use a torque wrench or an equivalent tool to ensure that the specified limits are not exceeded.

When selecting a part/material surrounding the COB LED in an LED spotlight (e.g. COB LED holder, TIM, etc.), it is important to consider its adverse effect on the COB LED. There may be gases released from parts/materials when exposed to heat/light and some of those gases may cause Nichia's COB LEDs to fail to illuminate or to degrade in performance. Examples of typical chemical compounds that could affect the COB LEDs and possible issues for each chemical compound group include:

Corrosive gases: Electrical connection failure resulting from chemical reactions in the COB LED electrode areas due to exposure to a corrosive environment.

Volatile organic compounds (VOC): Reduction in the luminous flux and/or color shift when VOCs penetrate the resin components (e.g. lens, encapsulating resin, dam wall, etc.) and discolor.

Halogen/phosphorus compounds: Adverse effect on the optical characteristics resulting from cracks in the resin components (e.g. lens, encapsulating resin, dam wall, etc.) due to exposure to halogen/phosphorus compounds.

Other important concerns are:

・If a COB LED holder/TIM is used, their characteristics/outline dimensions may change due to exposure to the heat/light, which may reduce the adhesion strength between the COB LED and COB LED holder, or the COB LED holder and housing/heatsink and result in the COB LED degrading in performance or failing to illuminate. Sufficient verification should be performed to ensure that there are no issues with the reliability of each component in the chosen application.

・If an electric connection is established by soldering electrical leads to the COB LED electrodes with hands, ensure that the leads are not pulled once soldered. Otherwise, this may cause the electrodes to become delaminated.

・Additionally, some solder pastes contain chemicals (e.g. halogens, etc.) that may reduce the adhesion strength between the COB LED electrodes and COB LED ceramic substrate. Take this into consideration when selecting a solder paste.

5.2 Housing/Heatsink Contact Surfaces

The condition of the housing/heatsink contact surface can affect the adhesion strength of the COB LED to it. If there are issues with the contact surface (e.g. uneven surface, burr/flash, hole/recess, foreign material, etc.), it may:

・significantly reduce the heat dissipation.

・damage the COB LED ceramic substrate when attaching to the housing/heatsink, even if the tightening torque is appropriate.

For further details on information provided in sections 5.1 and 5.2, refer to the following Nichia application notes:

1. Assembly and Handling Precautions for COB LEDs
2. Heat Dissipation Performance according to the Adhesion Strength of COB and Housing
3. How to Hand Solder an Electric Wire to a COB LED

5.3 COB LED Junction Temperature (T_J)

5.3.1 How to Calculate the Junction Temperature (T_J)

Using the suggestions above for effective heat dissipation, ensure that the junction temperature (T_J) does not exceed the absolute maximum junction temperature (T_{JMax}) detailed in the specification for the COB LEDs. The junction temperature (T_J) can be estimated from equation 1 below. For the thermal resistance ($R_{\theta JC}$), refer to the specification for each COB LED part number. Note that the $R_{\theta JC}$ may vary depending on each individual COB LED; to calculate the junction temperature (T_J) use the maximum $R_{\theta JC}$, instead of the typical $R_{\theta JC}$.

Equation 1: $T_J = T_C + R_{\theta JC} \times W$

T_J =	Junction Temperature [°C]
T_C =	Case Temperature [°C]
$R_{\theta JC}$ =	Thermal Resistance from Junction to T_C Measurement Point [°C/W][2]
W =	Input Power (I_F x V_F) [W]
I_F =	Forward Current [A]
V_F =	Forward Voltage [V]

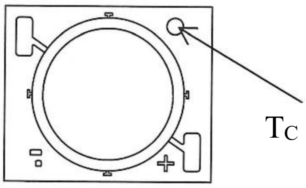


Figure 5. Position of the T_C measurement point

5.3.2 Cautions/Suggestions for Using a Thermal Imaging Camera

Nichia recommends using a non-contact temperature measuring instrument (e.g. thermal imaging camera) to measure the temperature of its COB LEDs for the thermal management design of the chosen application. Since the $R_{\theta JC}$ value can vary depending on the parts/material adjacent to the COB LED (i.e. the thermal conductivity of the TIM, the material properties/surface condition of the housing/heatsink), this method is very useful when:

・determining the surface temperature of the COB LED emission area

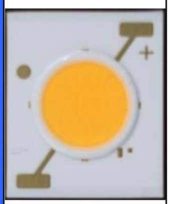
・verifying the evenness of the temperature distribution for the chosen design.

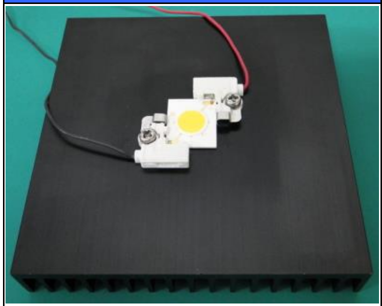
However, the temperature of the emission area obtained by thermal imaging is not an actual junction temperature (T_J). It should be used as a reference value to assess the validity of the calculated junction temperature (T_J).

Refer to Table 7 for an example of a calculated junction temperature (T_J) vs. thermal imaging camera measured COB LED temperature. A NFCLL036B COB LED was used for the temperature comparison. The calculated junction temperature (T_J) was obtained by measuring the T_C of this COB LED and then calculating from equation 1 above. The thermal imaging camera measured temperature was the maximum temperature when measuring the emission area of the same COB LED using a thermal imaging camera. As shown in Table 7 below, the results provide evidence for the validity of the calculated junction temperature (T_J) since it is very similar to the thermal imaging camera measured value. If there is a large gap between these values, it may indicate that there are issues with the assembly; examine to ensure that the COB LED is properly attached to the housing/heatsink.

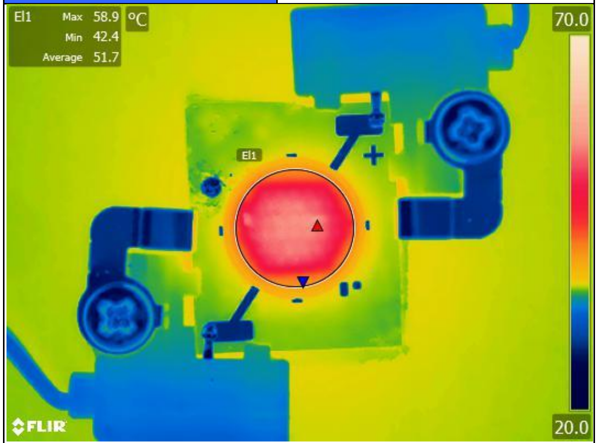
Note:
[2] Use the maximum $R_{\theta JC}$ detailed in the specification as $R_{\theta JC}$ may vary depending on each individual COB LED.

Table 7. Example of a T_J validity assessment using a thermal imaging camera

P/N	NFCLL036B
Appearance	
CCT	4000K
CRI Rank	R8000
$R_{\theta JC}$ (Max.)	2.1 °C/W

COB LED Attached to Heatsink

Attached the COB LED to the heatsink center with holders. Used thermal grease between the COB LED and heatsink.

Operating Conditions	Input Power	10 W
	Duration	60 min
T_C	38.7 °C	
T_J	$T_J = 38.7 + 2.1 \times 10 =$	**59.7** [°C]

Thermal Imaging Camera	FLIR T620	
		
Emission Area Surface Temperature[3]	**Max.**	**58.9** °C
	Min.	42.4 °C
	Avg.	51.7 °C

These two values are similar enough to conclude that the calculated T_J is valid.

5.3.3 Thermal Evaluation Precautions

When performing a thermal evaluation, ensure that:

・the estimated maximum ambient temperature is used

・the COB LED is placed and oriented in a manner as similar as possible to the COB LED in the chosen spotlight (e.g. projecting the light upwards, downwards, or horizontally, etc.)

・the COB LED is properly attached to the housing/heatsink in a manner that takes into consideration the conditions/environments in which the spotlight will actually be used.

Additionally, the junction temperature (T_J) may vary depending on each individual COB LED and/or other components being used with the COB LED (e.g. power supply, etc.) due to manufacturing variations. Ensure that the chosen design has sufficient margins/tolerances.

Note:
[3] The level of the temperature is indicated by the colors (High temp.= ▲ Low temp.= ▼)

5.4 Forward Current (I_F)

The COB LED driver IC must be designed to ensure that the absolute maximum rating current is not exceeded under any circumstances. Otherwise, it may cause the COB LED to degrade in performance or to fail to illuminate. If the LED driver IC produces a current waveform with noticeable periodic variation (i.e. ripple), the average value of the current flowing through the circuit may be lower than the absolute maximum rating current for the COB LEDs and yet the peak current may not. To ensure that this does not occur in the circuit of the chosen application, use an oscilloscope to verify that any part of the current waveform does not exceed the absolute maximum rating current.

Additionally, the chosen current should be determined taking into consideration its effect on the COB LED lifetime. Note that if more I_F is used, it increases the luminous flux; however, as follows from equation 1 above it results in an increase in the junction temperature (T_J) that may adversely affect the reliability/lifetime.

5.5 Dielectric Strength between the COB LED Live Parts and Housing/Heatsink

Electrical and electronic devices must provide sufficient dielectric strength according to the type of power supply (i.e. single-, three- or split-phase system) and the nominal voltage (i.e. the standard voltage of the region/country). E.g. A voltage of 2.5kV will be required for indoor commercial spotlights designed for a rated voltage of 100V AC.

A COB LED with a ceramic substrate will be effective in ensuring the dielectric strength between the COB live parts and housing/heatsink since ceramics are insulators. If the chosen design requires an additional solution to extend the creepage distance (e.g. using an insulation sheet for the interface), it may adversely affect the heat dissipation; perform sufficient verification to ensure that there are no issues with the dielectric strength and heat dissipation.

6. Special Color Rendering COB LEDs

Depending on the intended use, spotlights may be required to provide a special lighting effect to make the target object appear more attractive than it actually is. Nichia's special color rendering COB LEDs have been developed to focus on the qualitative aspects of light and designed for applications that require enhanced the color saturation (see Table 8).

This section provides basic information about the special color rendering COB LEDs and performance data comparing the color rendering of various objects between special color rendering COB LEDs and standard high-efficiency R8000 CRI rank NFCLL036B COB LEDs and high-CRI R9050 CRI rank COB LEDs. Note that the comparison data shown in Tables 9, 10, and 11 below are results obtained by measuring random samples; COB LEDs with the same part number/color rank as those used in the comparisons may vary in the emission spectrum/other values, and the results will not be guaranteed. Use the data for reference purposes only. For the special rendering COB LED product portfolio, refer to Nichia's website.

Table 8. Options for Nichia's Special Color Rendering COB LEDs

CRI Rank	Part Number Suffix (No longer used)	Intended Application
Rs020	M2	Meat
Rs030	M3	Produce (e.g. vegetables, fruits, flowers, etc.)
Rs075	M7	White Fabrics

6.1 Color Ranks for the Special Color Rendering COB LEDs

Figure 6 below shows the 3-step color ranks[4] for the special color rendering COB LEDs (i.e. Rs020/M2, Rs030/M3, and Rs075/M7) on the CIE chromaticity diagram.

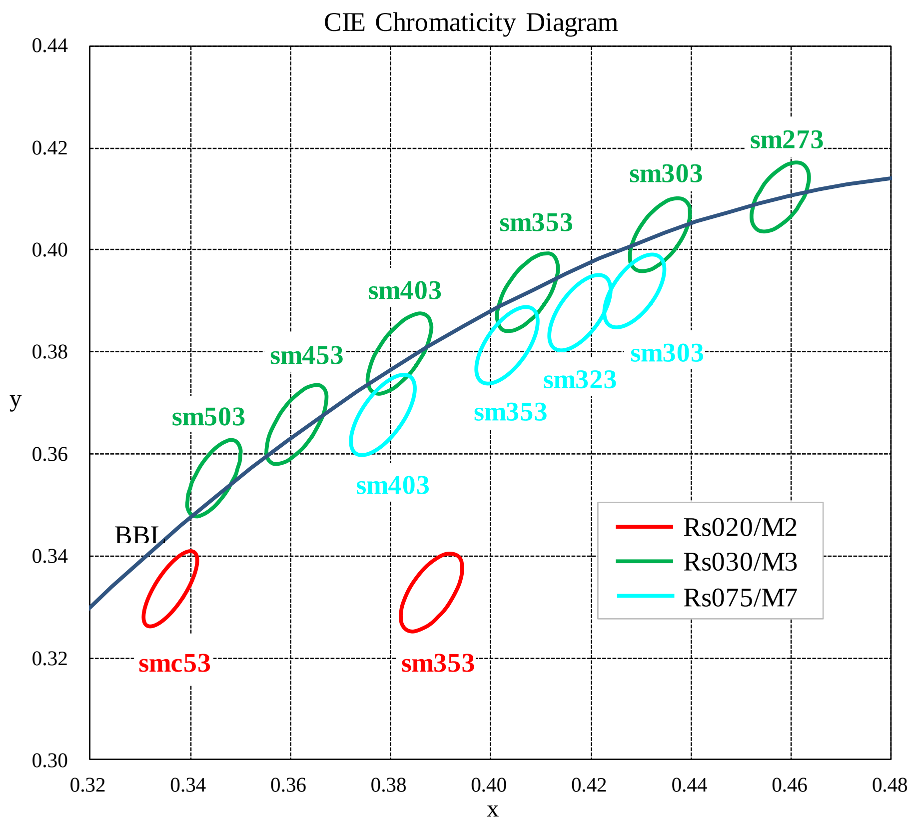


Figure 6. Color Ranks for the Special Color Rendering COB LEDs

6.2 Rs020 CRI Rank (Obsolete CRI P/N Suffix: M2) Special Color Rendering COB LEDs

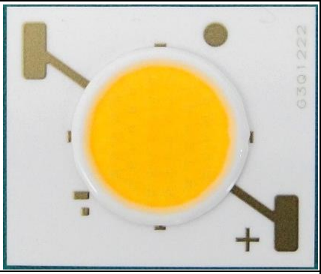
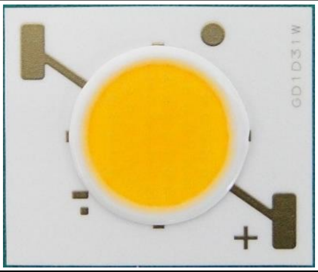
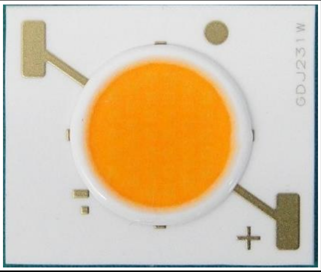
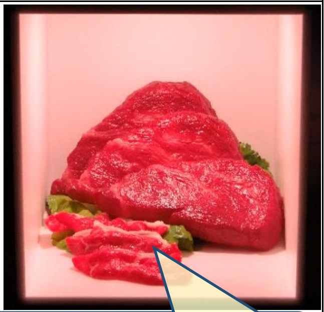
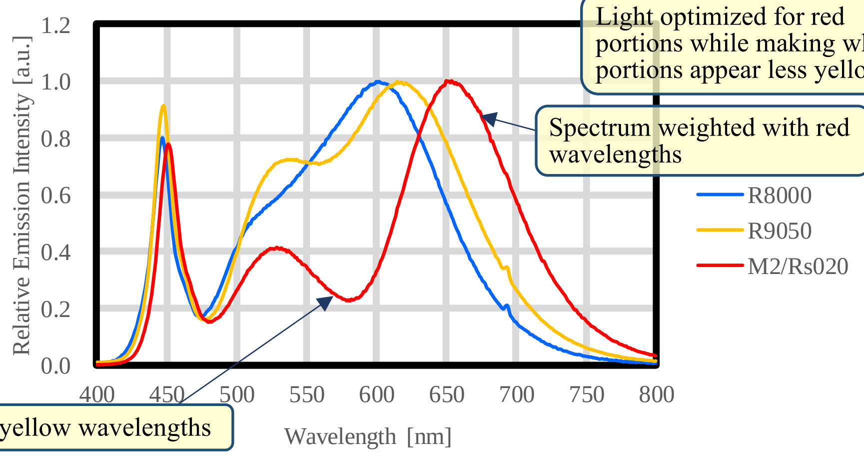
The Rs020 CRI Rank COB LEDs are designed to produce light that has more emphasis in the red wavelengths while reducing emission with yellow wavelengths; they enhance the redness in objects (e.g. meat) while making the white portions appear less yellow.

Table 9 shows an example of a comparison between the special color rendering NFCLL036B-M2 COB LED (equivalent CRI rank: Rs020, color rank: sm353g) and the high-efficiency NFCLL036B COB LED (CRI rank: R8000, color rank: sm353) or the high CRI NFCLL036B COB LED (CRI rank: R9050, color rank: sm353).

Note:
[4] Some Nichia COB LEDs have 2-step color ranks (i.e. smaller eclipses with the same center chromaticity coordinate as their corresponding 3-step eclipses).

Light Emitting Diode

Table 9. Color Appearance Comparison between a COB LEDs from Different CRI Ranks (Rs020/M2 vs. R8000 vs. R9050)

Part Number		NFCLL036B	NFCLL036B	NFCLL036B-M2
Color Rank		sm353	sm353	sm353g
CRI Rank		R8000	R9050	Equivalent CRI Rank: Rs020
COB LED Appearance Overview				
Forward Current (mA)		260	260	260
Forward Voltage (V)		36.0	36.0	36.0
Luminous Flux (lm)		1350	1130	635
Luminous Efficiency (lm/W)		144	121	68
Chromaticity Coordinates	x	0.413	0.409	0.388
	y	0.395	0.391	0.331
Color Appearance of the Object $T_A=25°C$ I_F=260mA				
Emission Spectrum				

CRI	Ra	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
R8000	83	82	89	96	83	82	86	85	64	12	75	83	71	83	98	75
R9050	92	95	93	90	92	94	91	93	87	66	83	92	75	95	93	92
M2/Rs020	57	47	74	85	46	49	68	72	18	-75	48	35	53	51	88	32

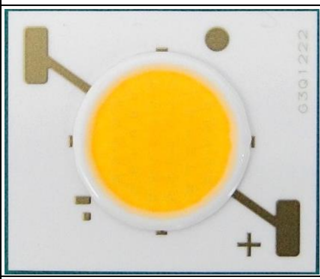
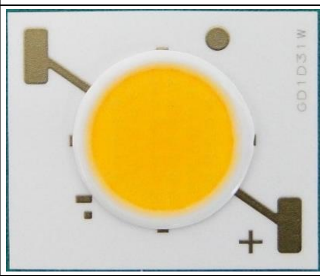
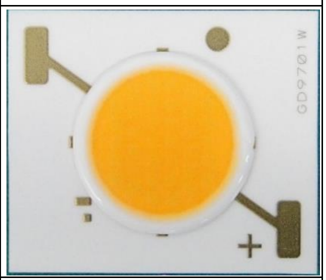
Note that the Rs020/M2 CRI rank COB LEDs do not faithfully reproduce the strong red test color (i.e. R9 value).

6.3 Rs030 CRI Rank (Obsolete CRI P/N Suffix: M3) Special Color Rendering COB LEDs

The Rs030 CRI Rank COB LEDs are designed to produce light with improved color saturation, with emphasis in the blue (i.e. LED die), green, and red wavelengths (phosphor); they enhance the fresh and healthy appearance of fruits and vegetables.

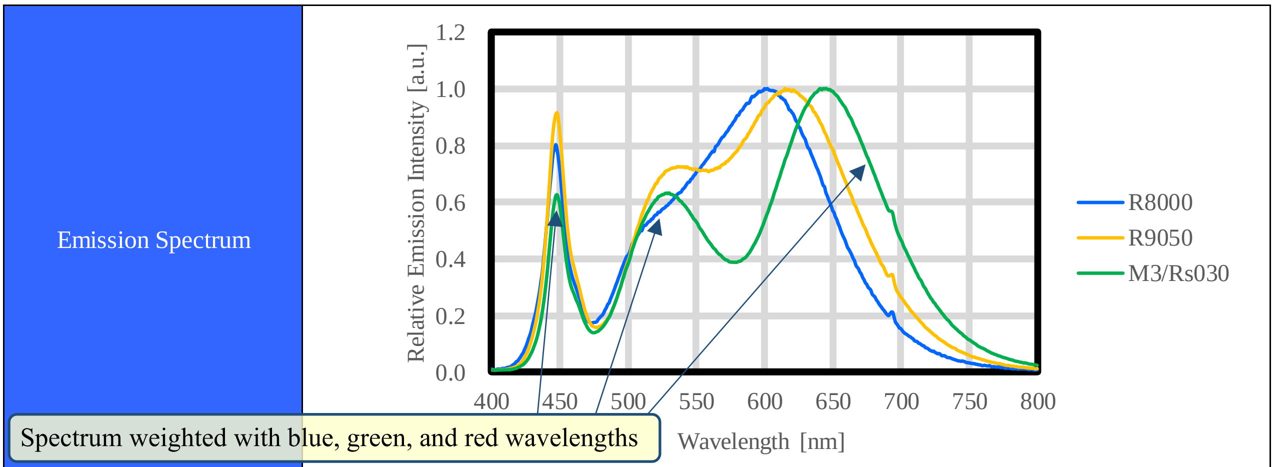
Table 10 shows an example of a comparison between the special color rendering NFCLL036B-M3 COB LED (equivalent CRI rank: Rs030, color rank: sm353) and the high-efficiency NFCLL036B COB LED (CRI rank: R8000, color rank: sm353) or the high CRI NFCLL036B COB LED (CRI rank: R9050, color rank: sm353).

Table 10. Color Appearance Comparison between a COB LEDs from Different CRI Ranks (Rs030/M3 vs. R8000 vs. R9050)

Part Number	NFCLL036B	NFCLL036B	NFCLL036B-M3
Color Rank	sm353	sm353	sm353
CRI Rank	R8000	R9050	Equivalent CRI Rank: Rs030
COB LED Appearance Overview			
Forward Current (mA)	260	260	260
Forward Voltage (V)	36.0	36.0	36.0
Luminous Flux (lm)	1350	1130	815
Luminous Efficiency (lm/W)	144	121	87
Chromaticity Coordinates x	0.413	0.409	0.408
Chromaticity Coordinates y	0.395	0.391	0.392
Color Appearance of the Object T_A=25°C I_F=260mA			

Light with improved color saturation

Emission Spectrum



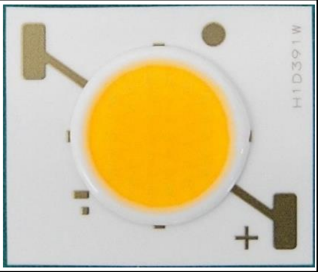
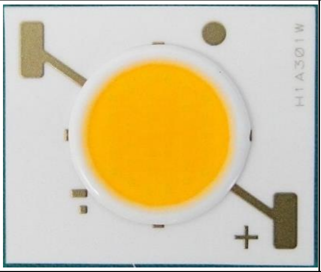
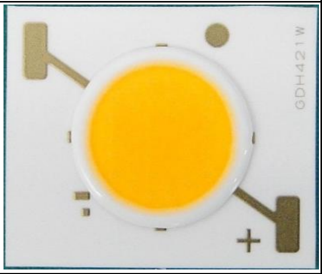
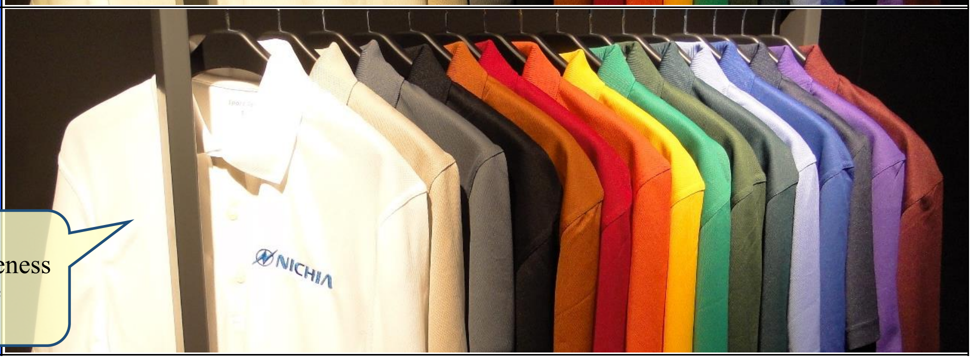
CRI	Ra	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
R8000	83	82	89	96	83	82	86	85	64	12	75	83	71	83	98	75
R9050	92	95	93	90	92	94	91	93	87	66	83	92	75	95	93	92
M3/Rs030	78	75	94	82	68	78	92	80	57	15	90	60	95	79	88	71

6.4 Rs075 CRI Rank (Obsolete CRI P/N Suffix: M7) Special Color Rendering COB LEDs

The Rs075 CRI Rank COB LEDs are designed to produce light that enhances the whiteness of objects with a special combination of phosphors while maintaining the high efficiency of standard high-efficiency COB LEDs; they are ideal light sources for clothing stores.

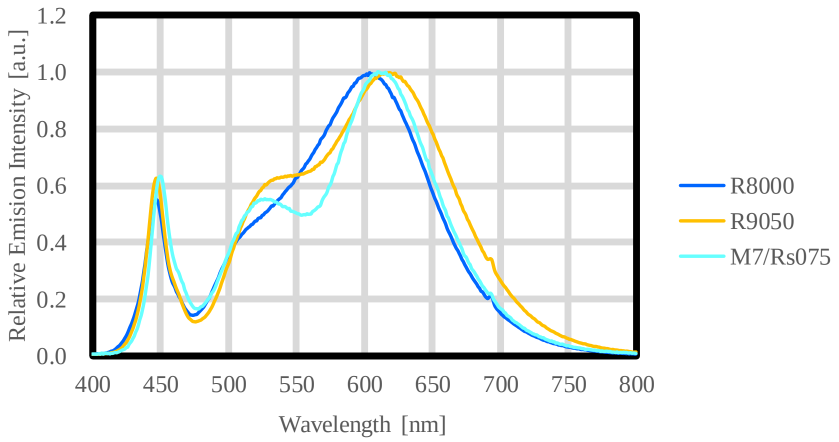
Table 11 shows an example of a comparison between the special color rendering NFCLL036B-M7 COB LED (equivalent CRI rank: Rs075, color rank: sm303j) and the high-efficiency NFCLL036B COB LED (CRI rank: R8000, color rank: sm303) or the high CRI NFCLL036B COB LED (CRI rank: R9050, color rank: sm303).

Table 11. Color Appearance Comparison between a COB LEDs from Different CRI Ranks (Rs075/M7 vs. R8000 vs. R9050)

Part Number		NFCLL036B	NFCLL036B	NFCLL036B-M7
Color Rank		sm303	sm303	sm303j
CRI Rank		R8000	R9050	Equivalent CRI Rank: Rs075
COB LED Appearance Overview				
Forward Current (mA)		260	260	260
Forward Voltage (V)		36.0	36.0	36.0
Luminous Flux (lm)		1310	1090	1155
Luminous Efficiency (lm/W)		140	116	123
Chromaticity Coordinates	x	0.435	0.436	0.428
	y	0.405	0.404	0.392
Color Appearance of the Object $T_A = 25°C$ I_F=260mA	R8000			
	R9050			
	M7/Rs075			

The COB LEDs produce light enhancing the whiteness of the target object while ensuring high efficiency.

Emission Spectrum



CRI	Ra	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
R8000	83	81	90	97	82	81	88	84	61	8	77	82	73	83	99	73
R9050	91	93	93	92	93	92	92	92	83	57	83	93	77	93	95	88
M7/Rs075	93	99	98	96	95	98	91	88	78	53	96	88	90	98	99	92

7. Summary

Nichia offers a wide variety of COB LEDs that are ideally suited in applications requiring the qualitative aspects of light in addition to the general requirements for high quality lighting grade COB LEDs (e.g. high luminous flux, low power consumption, long lifetime, high reliability, etc.). Along with ensuring proper thermal design and installation practices, Nichia's COB LEDs will make ideal light sources for spotlights in various places and situations – from commercial establishments to art galleries and museums, especially for heat/UV sensitive commodities (e.g. fresh foods, frozen processed foods, clothes, etc.) and artwork (e.g. paintings, photographs, etc.), which may require accurate color rendering, improved appearance of surface textures, and/or specific lighting effects.

This application note is intended to provide useful information and general cautions/suggestions when designing an LED spotlight using a Nichia COB LED. It is strongly recommended that all the information and precautions detailed in this application note are incorporated into the design and assembly practices to prevent premature failures of the COB LED.

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