

**NICHIA CORPORATION**

## **SPECIFICATIONS FOR WHITE LED**

### **NFMW481ART**

- Pb-free Reflow Soldering Application
- Built-in ESD Protection Device
- RoHS Compliant

# SPECIFICATIONS

## (1) Absolute Maximum Ratings

Item	Symbol	Absolute Maximum Rating	Unit
Forward Current	$I_F$	250	mA
Pulse Forward Current	$I_{FP}$	350	mA
Allowable Reverse Current	$I_R$	85	mA
Power Dissipation	$P_D$	6.15	W
Operating Temperature	$T_{opr}$	-40~100	°C
Storage Temperature	$T_{stg}$	-40~100	°C
Junction Temperature	$T_J$	135	°C

\* Absolute Maximum Ratings at  $T_J=25^\circ\text{C}$ .

\*  $I_{FP}$  conditions with pulse width  $\leq 10\text{ms}$  and duty cycle  $\leq 10\%$ .

\* For  $I_F$  and  $I_{FP}$ , see the "DERATING CHARACTERISTICS" of this specification.

## (2) Initial Electrical/Optical Characteristics

Item		Symbol	Condition	Typ	Max	Unit
Forward Voltage		$V_F$	$I_F=200\text{mA}$	22.9	-	V
			$I_F=90\text{mA}$	20.6	-	
R70	Luminous Flux (Chromaticity Coordinate1)	$\Phi_v$	$I_F=200\text{mA}$	660	-	lm
			$I_F=90\text{mA}$	321	-	
	Color Rendering Index (Chromaticity Coordinate1)	$R_a$	$I_F=200\text{mA}$	73	-	-
R8000	Luminous Flux (Chromaticity Coordinate1)	$\Phi_v$	$I_F=200\text{mA}$	600	-	lm
			$I_F=90\text{mA}$	292	-	
	Color Rendering Index (Chromaticity Coordinate1)	$R_a$	$I_F=200\text{mA}$	83	-	-
R9050	Luminous Flux (Chromaticity Coordinate1)	$\Phi_v$	$I_F=200\text{mA}$	510	-	lm
			$I_F=90\text{mA}$	250	-	
	Color Rendering Index (Chromaticity Coordinate1)	$R_a$	$I_F=200\text{mA}$	92	-	-
Chromaticity Coordinate1	x	-	$I_F=200\text{mA}$	0.4338	-	-
	y	-	$I_F=200\text{mA}$	0.4030	-	-
R70	Luminous Flux (Chromaticity Coordinate2)	$\Phi_v$	$I_F=200\text{mA}$	680	-	lm
			$I_F=90\text{mA}$	331	-	
	Color Rendering Index (Chromaticity Coordinate2)	$R_a$	$I_F=200\text{mA}$	73	-	-
R8000	Luminous Flux (Chromaticity Coordinate2)	$\Phi_v$	$I_F=200\text{mA}$	630	-	lm
			$I_F=90\text{mA}$	307	-	
	Color Rendering Index (Chromaticity Coordinate2)	$R_a$	$I_F=200\text{mA}$	83	-	-
R9050	Luminous Flux (Chromaticity Coordinate2)	$\Phi_v$	$I_F=200\text{mA}$	540	-	lm
			$I_F=90\text{mA}$	265	-	
	Color Rendering Index (Chromaticity Coordinate2)	$R_a$	$I_F=200\text{mA}$	92	-	-
Chromaticity Coordinate2	x	-	$I_F=200\text{mA}$	0.3447	-	-
	y	-	$I_F=200\text{mA}$	0.3553	-	-
Thermal Resistance		$R_{\theta JS}$	-	3.3	3.8	°C/W

\* Characteristics at  $T_J=25^\circ\text{C}$  and measured in pulse mode.

\* Optical Characteristics as per CIE 127:2007 standard.

\* Chromaticity Coordinates as per CIE 1931 Chromaticity Chart.

\*  $R_{\theta JS}$  is the thermal resistance from the junction to the  $T_S$  measurement point.

\*  $R_{\theta JS}$  is measured using the Dynamic Mode detailed in JESD51-1.

RANKS

Item	Rank	Condition	Min	Max	Unit
Forward Voltage	-	$I_F=200\text{mA}$	21.3	24.6	V
Luminous Flux	Pf0061	$I_F=200\text{mA}$	610	750	lm
	Pf0059		590	730	
	Pf0058		580	700	
	Pf0057		570	700	
	Pf0056		560	680	
	Pf0055		550	680	
	Pf0054		540	660	
	Pf0051		510	620	
	Pf0049		490	600	
	Pf0048		480	590	
	Pf0046		460	570	
	Pf0045		450	550	
	Pf0043		430	520	
	Pf0040		400	480	
Color Rendering Index	R70	$R_a$	70	-	-
	R8000	$R_a$	80	-	-
		$R_9$	0	-	-
	R9050	$R_a$	90	-	-
		$R_9$	50	-	-

Color Ranks( $I_F=200\text{mA}$ )

The color rank has a chromaticity range within a 3-step MacAdam ellipse.

		Rank sm203	Rank sm223	Rank sm253	Rank sm273	Rank sm303	Rank sm353
Color Temperature (Unit: K)	$T_{CP}$	2000	2200	2500	2700	3000	3500
Center Point	x	0.5270	0.5018	0.4806	0.4578	0.4338	0.4073
	y	0.4130	0.4153	0.4141	0.4101	0.4030	0.3917
Minor Axis	a	0.003978	0.004002	0.004029	0.004056	0.004107	0.004098
Major Axis	b	0.007062	0.007206	0.007515	0.007872	0.008391	0.008796
Ellipse Rotation Angle	$\Phi$	-43.56	-39.89	-37.58	-36.05	-36.00	-35.47

		Rank sm403	Rank sm453	Rank sm503	Rank sm573	Rank sm653
Color Temperature (Unit: K)	$T_{CP}$	4000	4500	5000	5700	6500
Center Point	x	0.3818	0.3611	0.3447	0.3287	0.3123
	y	0.3797	0.3658	0.3553	0.3417	0.3282
Minor Axis	a	0.004071	0.003852	0.003555	0.003087	0.002709
Major Axis	b	0.009282	0.009009	0.008418	0.007809	0.006561
Ellipse Rotation Angle	$\Phi$	-35.95	-34.33	-31.78	-31.56	-32.35

The color rank has a chromaticity range within a 5-step MacAdam ellipse.

		Rank sm2050a	Rank sm2050b	Rank sm2050c	Rank sm2050d	Rank sm2050e	Rank sm2050f
Color Temperature (Unit: K)	T <sub>CP</sub>	2000					
Center Point	x	0.5270					
	y	0.4130					
Minor Axis	a	0.006630					
Major Axis	b	0.011770					
Ellipse Rotation Angle	Φ	-43.56					

		Rank sm2250a	Rank sm2250b	Rank sm2250c	Rank sm2250d	Rank sm2250e	Rank sm2250f
Color Temperature (Unit: K)	T <sub>CP</sub>	2200					
Center Point	x	0.5018					
	y	0.4153					
Minor Axis	a	0.006670					
Major Axis	b	0.012010					
Ellipse Rotation Angle	Φ	-39.89					

		Rank sm2550a	Rank sm2550b	Rank sm2550c	Rank sm2550d	Rank sm2550e	Rank sm2550f
Color Temperature (Unit: K)	T <sub>CP</sub>	2500					
Center Point	x	0.4806					
	y	0.4141					
Minor Axis	a	0.006715					
Major Axis	b	0.012525					
Ellipse Rotation Angle	Φ	-37.58					

		Rank sm2750a	Rank sm2750b	Rank sm2750c	Rank sm2750d	Rank sm2750e	Rank sm2750f
Color Temperature (Unit: K)	T <sub>CP</sub>	2700					
Center Point	x	0.4578					
	y	0.4101					
Minor Axis	a	0.006760					
Major Axis	b	0.013120					
Ellipse Rotation Angle	Φ	-36.05					

		Rank sm3050a	Rank sm3050b	Rank sm3050c	Rank sm3050d	Rank sm3050e	Rank sm3050f
Color Temperature (Unit: K)	T <sub>CP</sub>	3000					
Center Point	x	0.4338					
	y	0.4030					
Minor Axis	a	0.006845					
Major Axis	b	0.013985					
Ellipse Rotation Angle	Φ	-36.00					

		Rank sm3550a	Rank sm3550b	Rank sm3550c	Rank sm3550d	Rank sm3550e	Rank sm3550f
Color Temperature (Unit: K)	T <sub>CP</sub>	3500					
Center Point	x	0.4073					
	y	0.3917					
Minor Axis	a	0.006830					
Major Axis	b	0.014660					
Ellipse Rotation Angle	Φ	-35.47					

		Rank sm4050a	Rank sm4050b	Rank sm4050c	Rank sm4050d	Rank sm4050e	Rank sm4050f
Color Temperature (Unit: K)	T <sub>CP</sub>	4000					
Center Point	x	0.3818					
	y	0.3797					
Minor Axis	a	0.006785					
Major Axis	b	0.015470					
Ellipse Rotation Angle	Φ	-35.95					

		Rank sm4550a	Rank sm4550b	Rank sm4550c	Rank sm4550d	Rank sm4550e	Rank sm4550f
Color Temperature (Unit: K)	T <sub>CP</sub>	4500					
Center Point	x	0.3611					
	y	0.3658					
Minor Axis	a	0.006420					
Major Axis	b	0.015015					
Ellipse Rotation Angle	Φ	-34.33					

		Rank sm5050a	Rank sm5050b	Rank sm5050c	Rank sm5050d	Rank sm5050e	Rank sm5050f
Color Temperature (Unit: K)	T <sub>CP</sub>	5000					
Center Point	x	0.3447					
	y	0.3553					
Minor Axis	a	0.005925					
Major Axis	b	0.014030					
Ellipse Rotation Angle	Φ	-31.78					

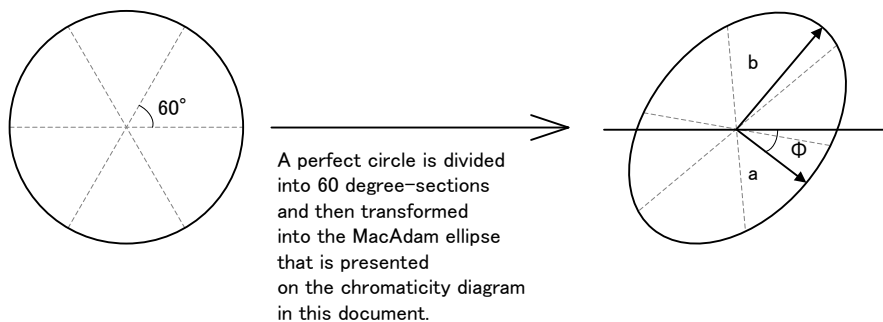
		Rank sm5750a	Rank sm5750b	Rank sm5750c	Rank sm5750d	Rank sm5750e	Rank sm5750f
Color Temperature (Unit: K)	T <sub>CP</sub>	5700					
Center Point	x	0.3287					
	y	0.3417					
Minor Axis	a	0.005145					
Major Axis	b	0.013015					
Ellipse Rotation Angle	Φ	-31.56					

		Rank sm6550a	Rank sm6550b	Rank sm6550c	Rank sm6550d	Rank sm6550e	Rank sm6550f
Color Temperature (Unit: K)	$T_{CP}$	6500					
Center Point	x	0.3123					
	y	0.3282					
Minor Axis	a	0.004515					
Major Axis	b	0.010935					
Ellipse Rotation Angle	$\Phi$	-32.35					

- \* Ranking at  $T_J=25^{\circ}C$  and measured in pulse mode.
- \* Forward Voltage Tolerance:  $\pm 0.2V$
- \* Luminous Flux Tolerance:  $\pm 5\%$
- \* Color Rendering Index  $R_a$  Tolerance:  $\pm 2$
- \* Color Rendering Index  $R_9$  Tolerance:  $\pm 6.5$
- \* The  $R_9$  value for the above rank shall be greater than 0.
- \* Chromaticity Coordinate Tolerance:  $\pm 0.003$
- \* LEDs from the above ranks will be shipped.

The rank combination ratio per shipment will be decided by Nichia.

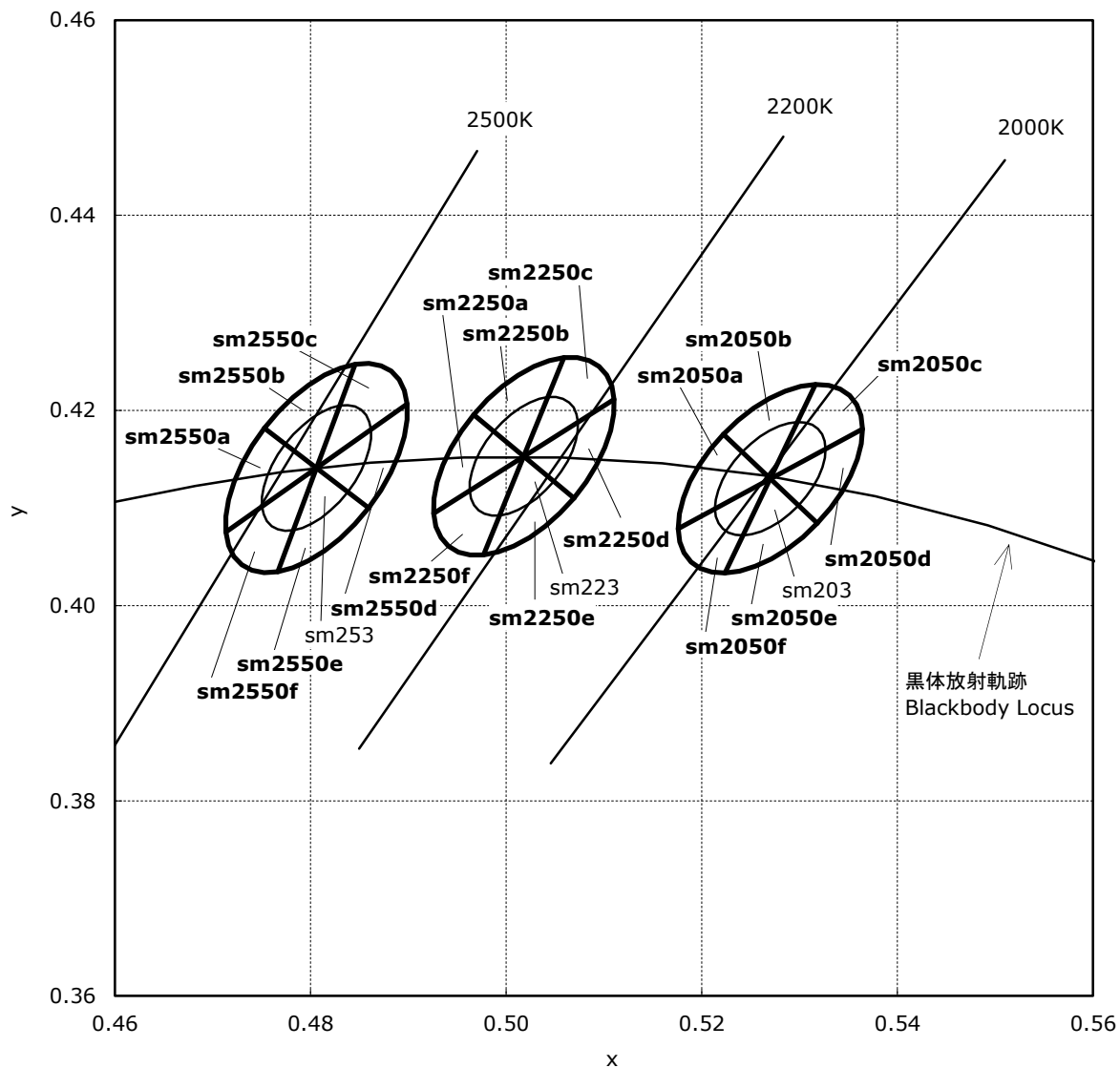
Definition of the MacAdam ellipse ranks:



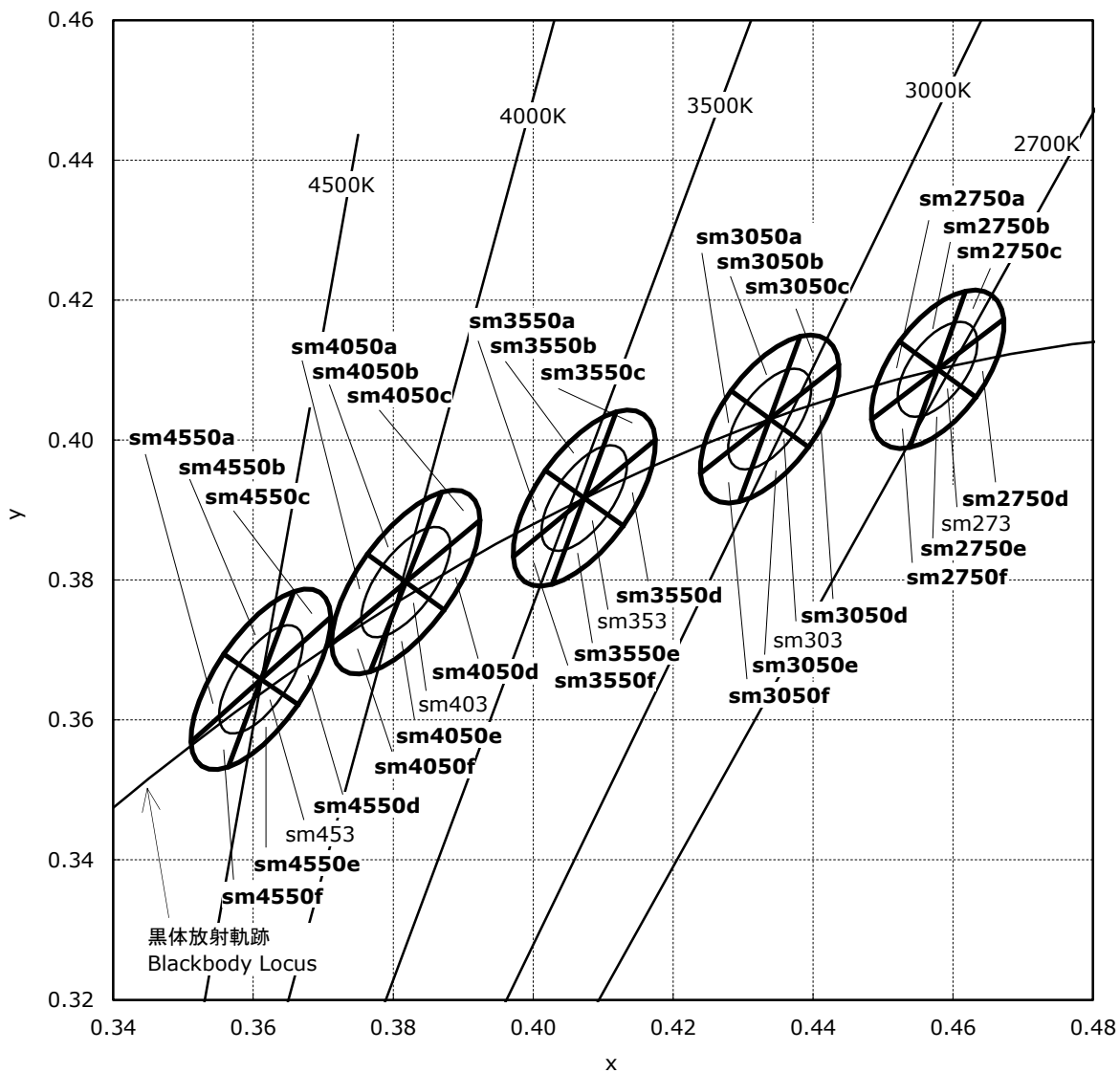
Luminous Flux Ranks by Color Rank, Color Rendering Index Rank

Color Coordinates	Color Rendering Index	Luminous Flux
sm203, sm2050a, sm2050b, sm2050c, sm2050d, sm2050e, sm2050f	R8000	Pf0040
sm223, sm2250a, sm2250b, sm2250c, sm2250d, sm2250e, sm2250f	R8000	Pf0045
sm253, sm2550a, sm2550b, sm2550c, sm2550d, sm2550e, sm2550f	R8000	Pf0048
sm273, sm2750a, sm2750b, sm2750c, sm2750d, sm2750e, sm2750f	R70	Pf0058
	R8000	Pf0051
	R9050	Pf0043
sm303, sm3050a, sm3050b, sm3050c, sm3050d, sm3050e, sm3050f	R70	Pf0059
	R8000	Pf0054
	R9050	Pf0046
sm353, sm3550a, sm3550b, sm3550c, sm3550d, sm3550e, sm3550f	R70	Pf0061
	R8000	Pf0055
	R9050	Pf0048
sm403, sm4050a, sm4050b, sm4050c, sm4050d, sm4050e, sm4050f	R70	Pf0061
	R8000	Pf0056
	R9050	Pf0049
sm453, sm4550a, sm4550b, sm4550c, sm4550d, sm4550e, sm4550f	R70	Pf0061
	R8000	Pf0056
	R9050	Pf0049
sm503, sm5050a, sm5050b, sm5050c, sm5050d, sm5050e, sm5050f	R70	Pf0061
	R8000	Pf0057
	R9050	Pf0049
sm573, sm5750a, sm5750b, sm5750c, sm5750d, sm5750e, sm5750f	R70	Pf0061
	R8000	Pf0057
sm653, sm6550a, sm6550b, sm6550c, sm6550d, sm6550e, sm6550f	R70	Pf0059
	R8000	Pf0056

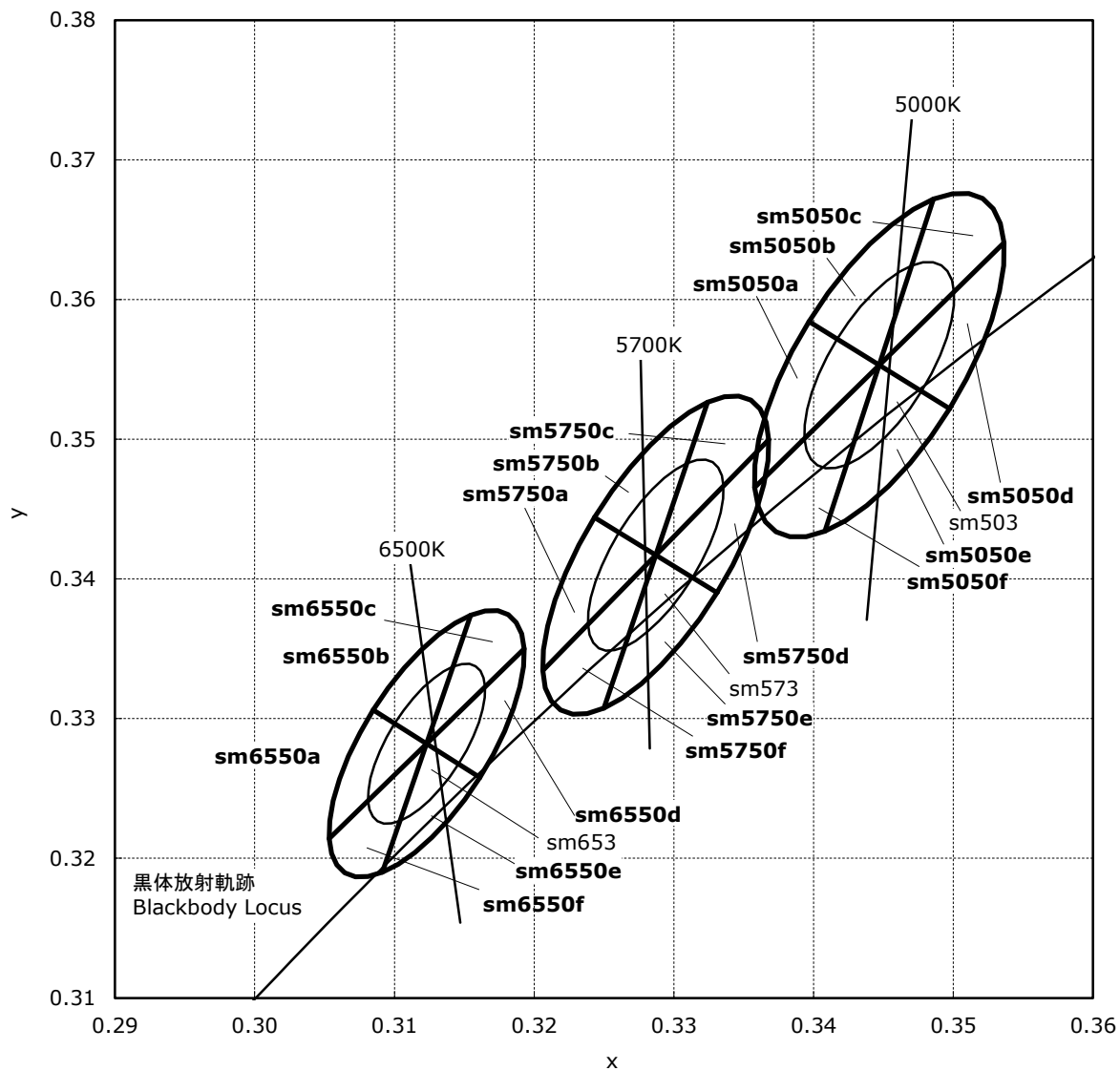
# CHROMATICITY DIAGRAM



# CHROMATICITY DIAGRAM



# CHROMATICITY DIAGRAM



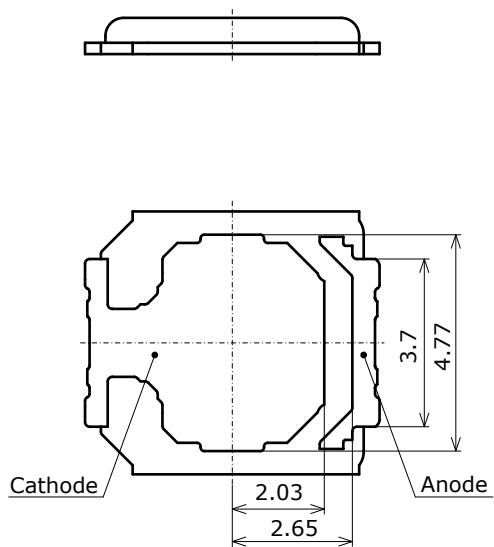
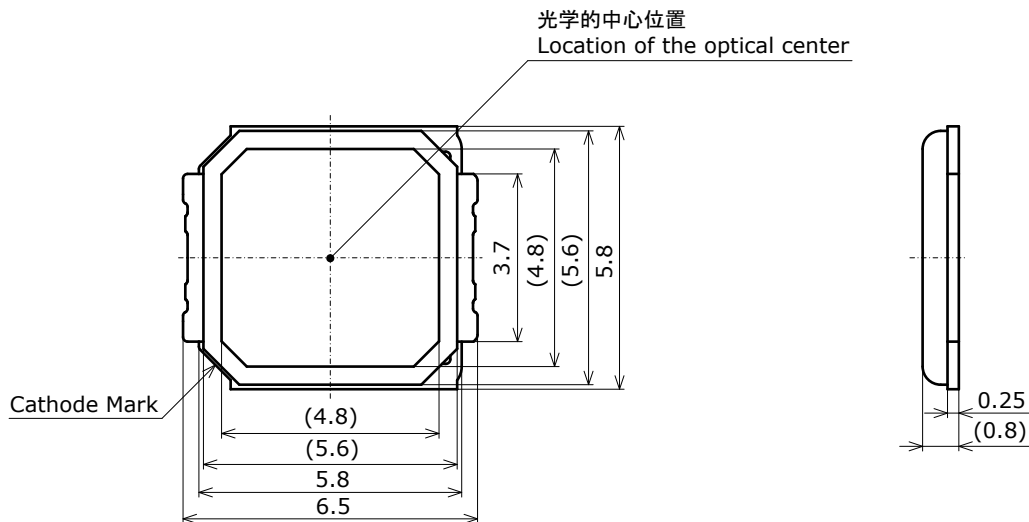
# OUTLINE DIMENSIONS

\* 本製品はRoHS指令に適合しております。  
This product complies with RoHS Directive.

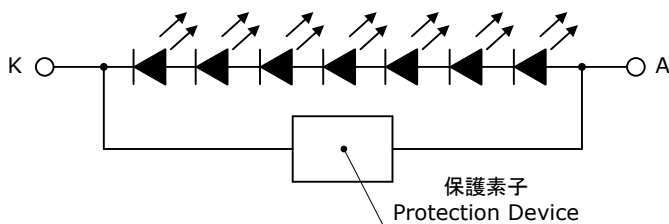
NFMW481AR  
管理番号 No. STS-DA7-10559

\* 括弧で囲まれた寸法は参考値です。  
The dimension(s) in parentheses are for reference purposes.

(単位 Unit: mm, 公差 Tolerance: ±0.2)

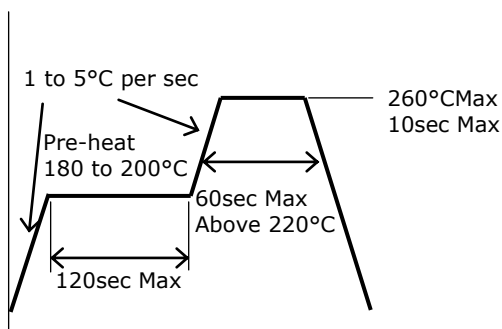


項目 Item	内容 Description
パッケージ材質 Package Materials	耐熱性ポリマー Heat-Resistant Polymer
封止樹脂材質 Encapsulating Resin Materials	シリコン樹脂 (拡散剤+蛍光体入り) Silicone Resin (with diffuser and phosphor)
電極材質 Electrodes Materials	銅合金+銀メッキ Ag-plated Copper Alloy
質量 Weight	0.077g(TYP)

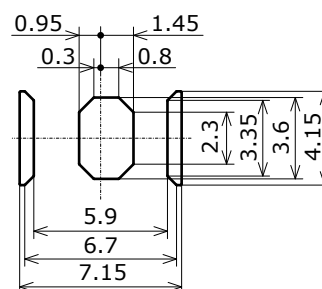
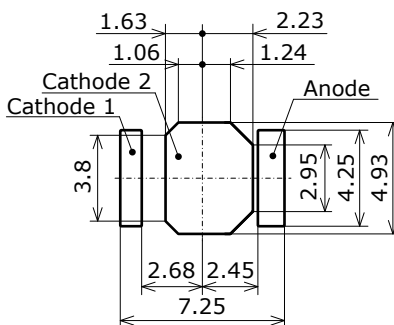
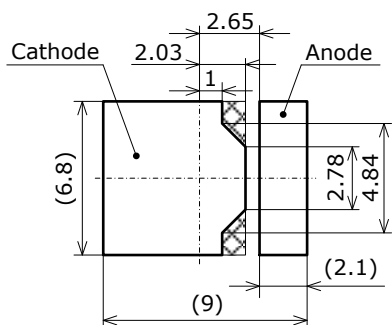


# SOLDERING

- Recommended Reflow Soldering Condition(Lead-free Solder)



- Recommended Soldering Pad Pattern
- Recommended Solder Resist Opening
- Recommended Metal Solder Stencil Aperture



☒ 交差斜線部にランドパターンを配置しないでください。  
 Do not have the solder pads in the area shaded with crossed diagonal lines.

(単位 Unit: mm)

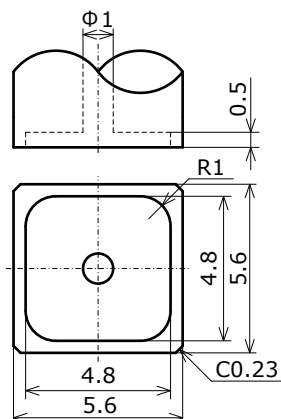
Cathode 1 and Cathode 2 should be soldered to a PCB.

- \* This LED is designed to be reflow soldered on to a PCB. If dip soldered or hand soldered, Nichia cannot guarantee its reliability.
- \* Reflow soldering must not be performed more than twice.
- \* Avoid rapid cooling. Ramp down the temperature gradually from the peak temperature.
- \* Nitrogen reflow soldering is recommended. Air flow soldering conditions can cause optical degradation, caused by heat and/or atmosphere.
- \* Since the silicone used in the encapsulating resin is soft, do not press on the encapsulant resin. Pressure can cause nicks, chip-outs, encapsulant delamination and deformation, and wire breaks, decreasing reliability. When using automatic pick and place machine, use a pick up nozzle which does not directly apply stress to the encapsulation of the LEDs.

Recommended conditions:

It is recommended to use a pick up nozzle designed for the LEDs. (See Figure below.)

- \* If the LEDs are picked and placed by a nozzle that does not comply with the recommended conditions, it may cause the wires to break and the LED not to illuminate.



(単位 Unit: mm)

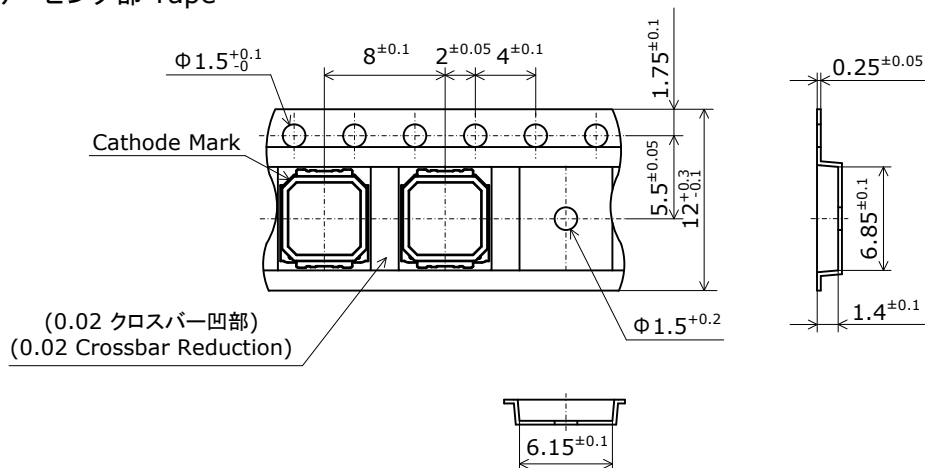
- \* Repairing should not be done after the LEDs have been soldered. When repairing is unavoidable, a hot plate should be used.  
It should be confirmed beforehand whether the characteristics of the LEDs will or will not be damaged by repairing.
- \* The Cathode 2 should be soldered to customer PCB.  
If it is difficult or impossible, use high heat-dissipating adhesive.
- \* When soldering, do not apply stress to the LED while the LED is hot.
- \* When using a pick and place machine, choose an appropriate nozzle for this product. Using a pick-and-place nozzle with a smaller diameter than the size of the LED's emitting surface will cause damage to the emitting surface and may also cause the LED not to illuminate.
- \* The recommended soldering pad pattern is designed for attachment of the LED without problems.  
When precise mounting accuracy is required, such as high-density mounting, ensure that the size and shape of the pad are suitable for the circuit design.
- \* When flux is used, it should be a halogen free flux. Ensure that the manufacturing process is not designed in a manner where the flux will come in contact with the LEDs.
- \* Make sure that there are no issues with the type and amount of solder that is being used.

# TAPE AND REEL DIMENSIONS

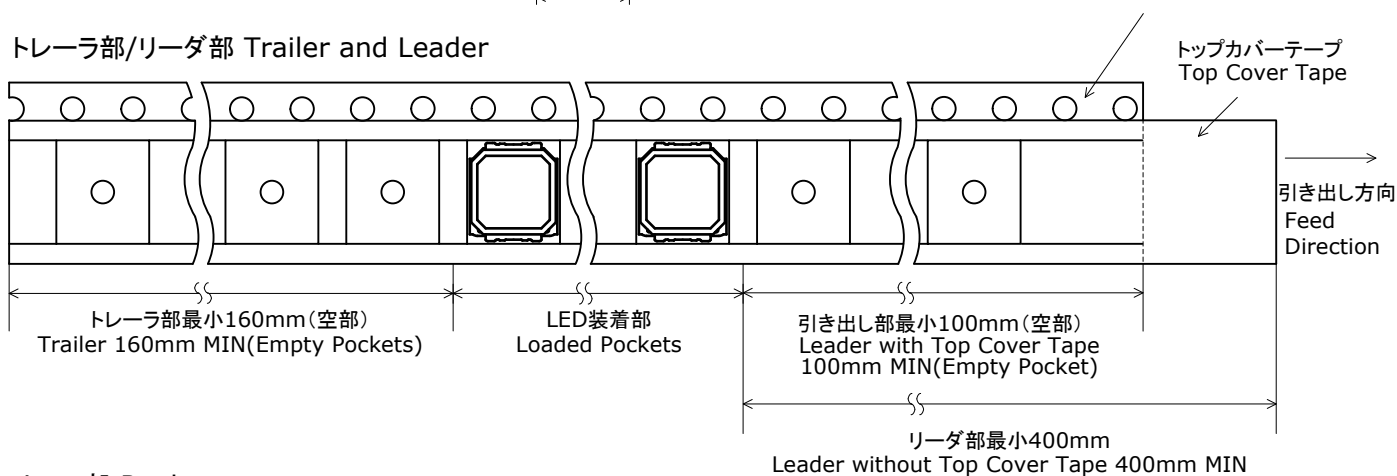
## テーピング部 Tape

Nxxx481x  
管理番号 No. STS-DA7-10560

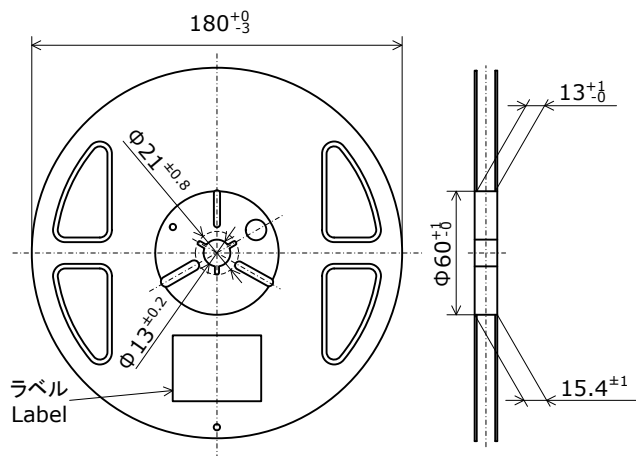
(単位 Unit: mm)



## トレーラ部/リーダ部 Trailer and Leader



## リール部 Reel

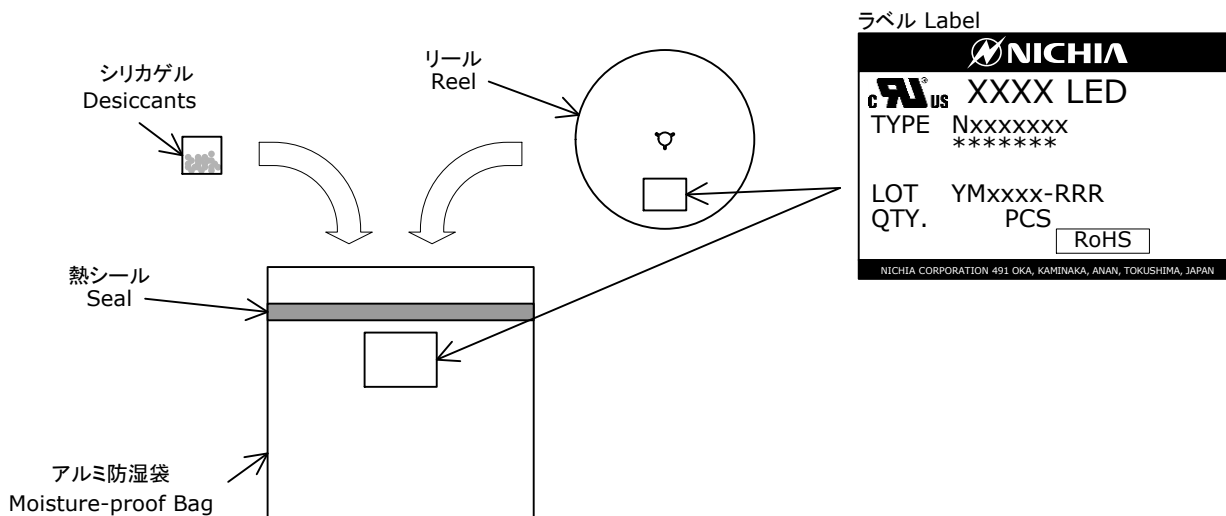


- \* 数量は1リールにつき 1500個入りです。  
Reel Size: 1500pcs
- \* 実装作業の中断などでエンボスキャリアテープをリールに巻き取る場合、エンボスキャリアテープを強く(10N以上)締めないで下さい。  
LEDがカバーテープに貼り付く可能性があります。  
When the tape is rewound due to work interruptions, no more than 10N should be applied to the embossed carrier tape.  
The LEDs may stick to the top cover tape.
- \* JIS C 0806電子部品テーピングに準拠しています。  
The tape packing method complies with JIS C 0806 (Packaging of Electronic Components on Continuous Tapes).

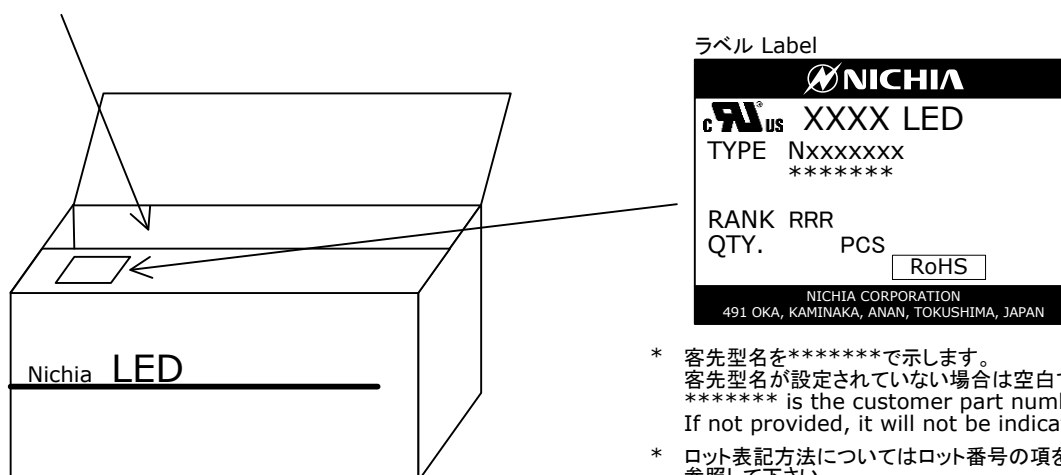
## PACKAGING - TAPE & REEL

シリカゲルとともにリールをアルミ防湿袋に入れ、熱シールにより封をします。  
 Reels are shipped with desiccants in heat-sealed moisture-proof bags.

Nxxxxxxx  
 管理番号 No. STS-DA7-4989



アルミ防湿袋を並べて入れ、ダンボールで仕切ります。  
 Moisture-proof bags are packed in cardboard boxes with corrugated partitions.



- \* 客先型名を\*\*\*\*\*で示します。  
 客先型名が設定されていない場合は空白です。  
 \*\*\*\*\* is the customer part number.  
 If not provided, it will not be indicated on the label.
- \* ロット表記方法についてはロット番号の項を参照して下さい。  
 For details, see "LOT NUMBERING CODE" in this document.
- \* ランク分けがない場合はランク表記はありません。  
 The label does not have the RANK field for un-ranked products.

- \* 本製品はテーピングしたのち、輸送の衝撃から保護するためダンボールで梱包します。  
 Products shipped on tape and reel are packed in a moisture-proof bag.  
 They are shipped in cardboard boxes to protect them from external forces during transportation.
- \* 取り扱いに際して、落下させたり、強い衝撃を与えたりしますと、製品を損傷させる原因になりますので注意して下さい。  
 Do not drop or expose the box to external forces as it may damage the products.
- \* ダンボールには防水加工がされておりませんので、梱包箱が水に濡れないよう注意して下さい。  
 Do not expose to water. The box is not water-resistant.
- \* 輸送、運搬に際して弊社よりの梱包状態あるいは同等の梱包を行って下さい。  
 Using the original package material or equivalent in transit is recommended.

# LOT NUMBERING CODE

Lot Number is presented by using the following alphanumeric code.

YMxxxx - RRR

Y - Year

Year	Y
2016	G
2017	H
2018	I
2019	J
2020	K
2021	L

M - Month

Month	M	Month	M
1	1	7	7
2	2	8	8
3	3	9	9
4	4	10	A
5	5	11	B
6	6	12	C

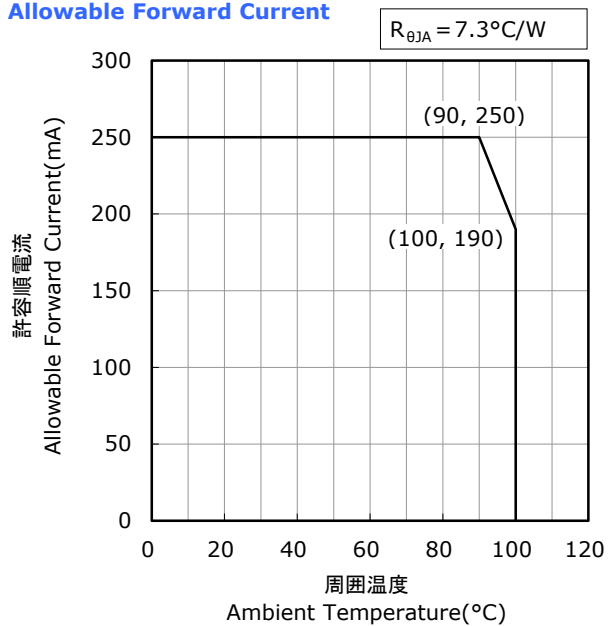
xxxx-Nichia's Product Number

RRR-Ranking by Color Coordinates, Ranking by Luminous Flux, Ranking by Color Rendering Index

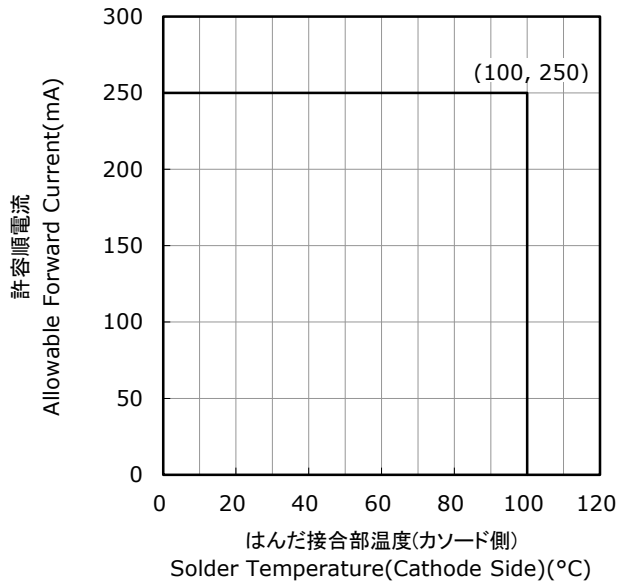
# DERATING CHARACTERISTICS

NFMW481AR  
管理番号 No. STS-DA7-10416

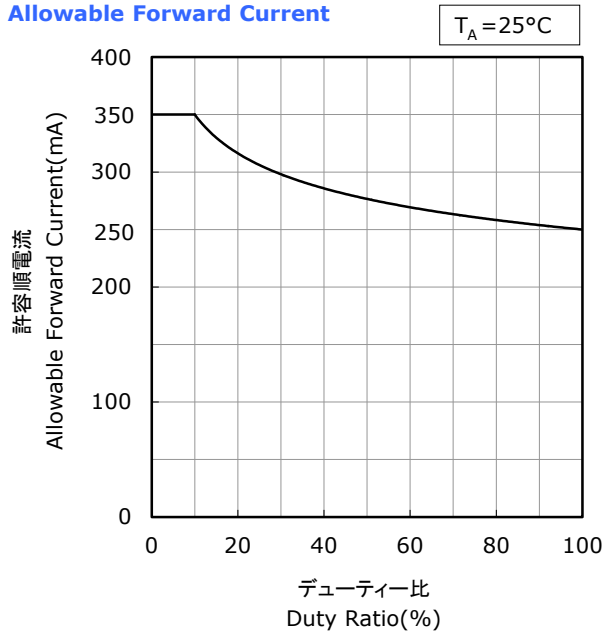
周囲温度-許容順電流特性  
Ambient Temperature vs  
Allowable Forward Current



はんだ接合部温度(カソード側)-許容順電流特性  
Solder Temperature(Cathode Side) vs  
Allowable Forward Current



デューティー比-許容順電流特性  
Duty Ratio vs  
Allowable Forward Current

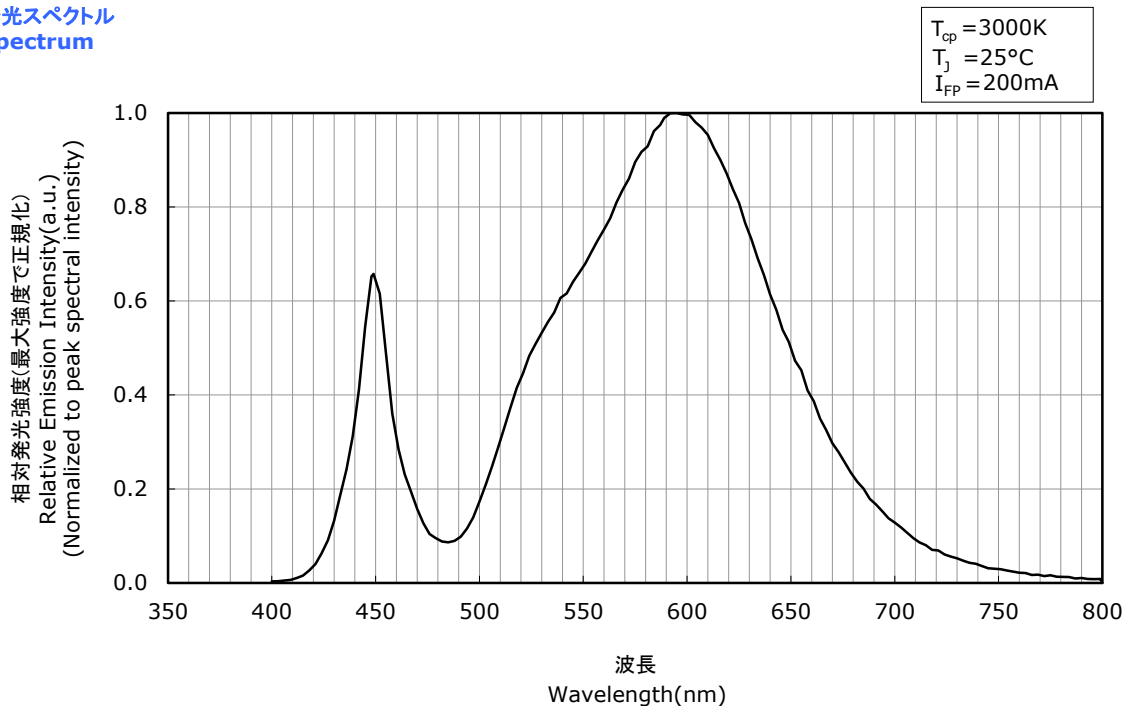


# OPTICAL CHARACTERISTICS

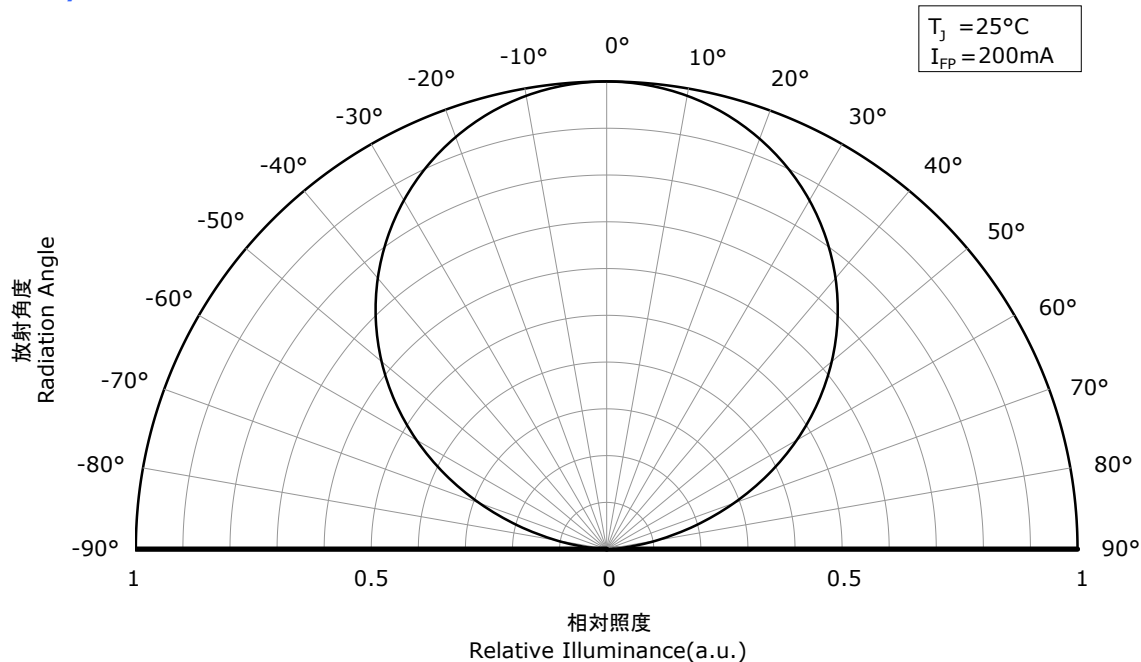
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10417A

## 発光スペクトル Spectrum



## 指向特性 Directivity



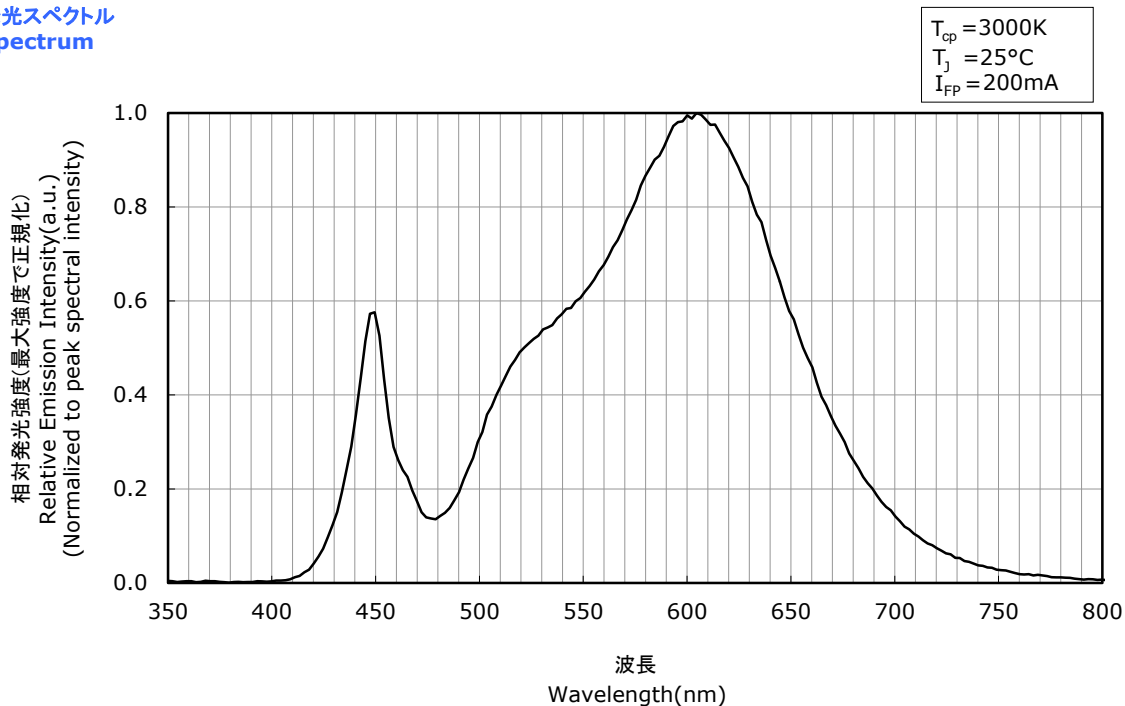
- \* 本特性は演色性ランクR70に対応しています。  
The graphs above show the characteristics for R70 LEDs of this product.

# OPTICAL CHARACTERISTICS

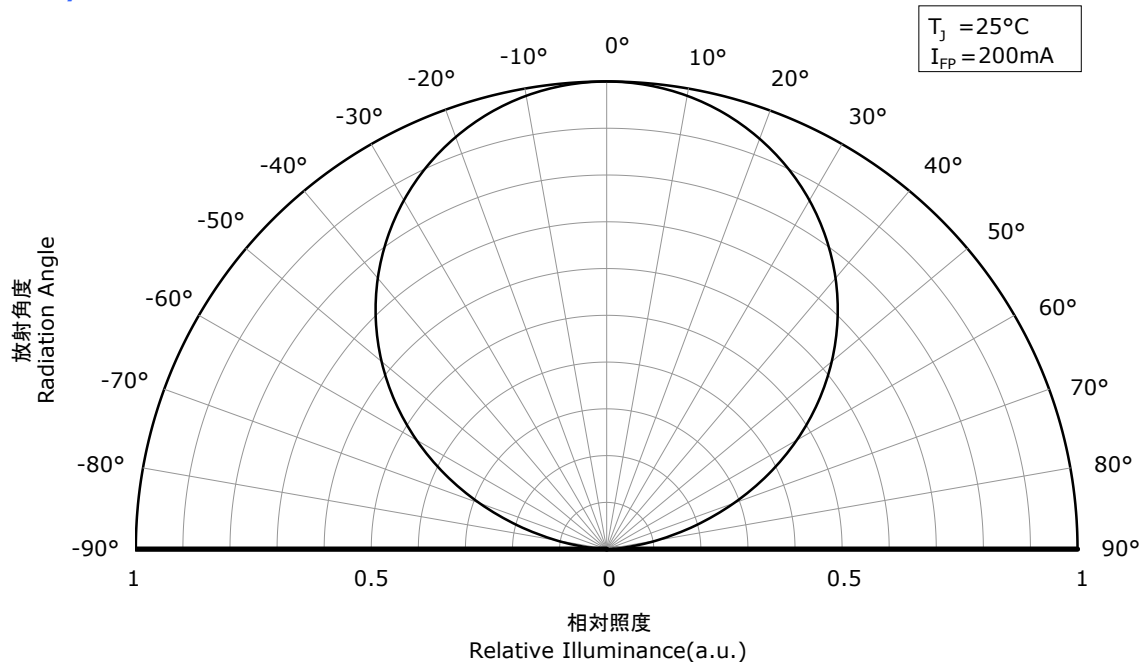
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10418A

## 発光スペクトル Spectrum



## 指向特性 Directivity



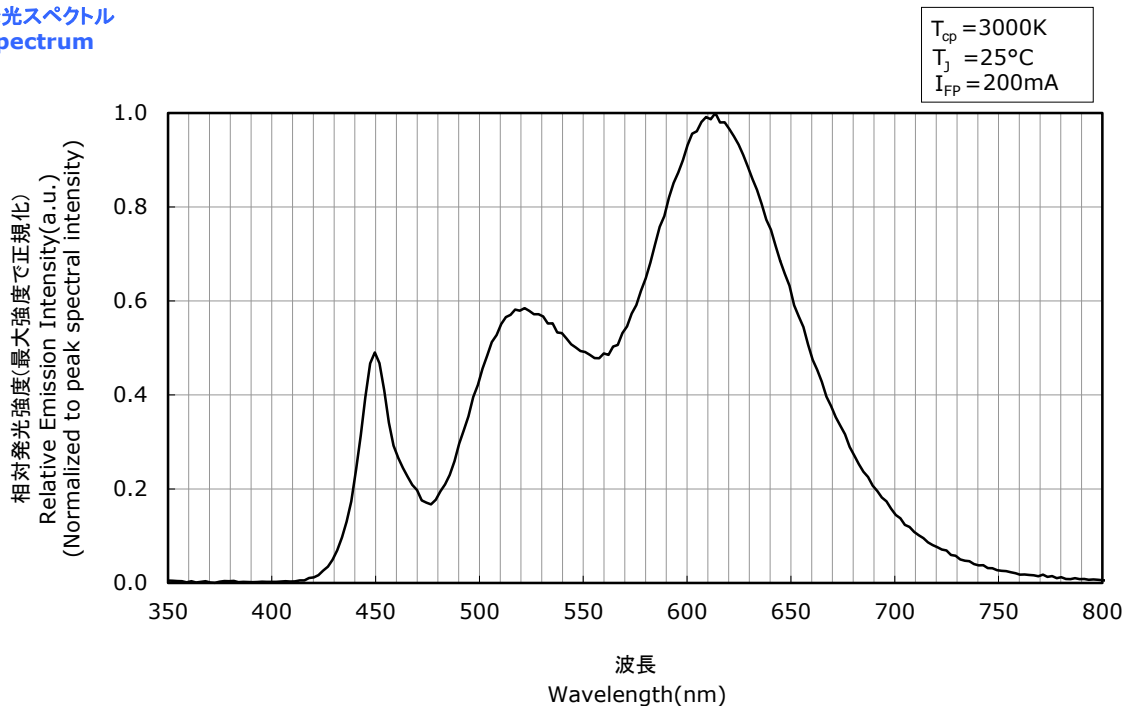
- \* 本特性は演色性ランクR8000に対応しています。  
The graphs above show the characteristics for R8000 LEDs of this product.

# OPTICAL CHARACTERISTICS

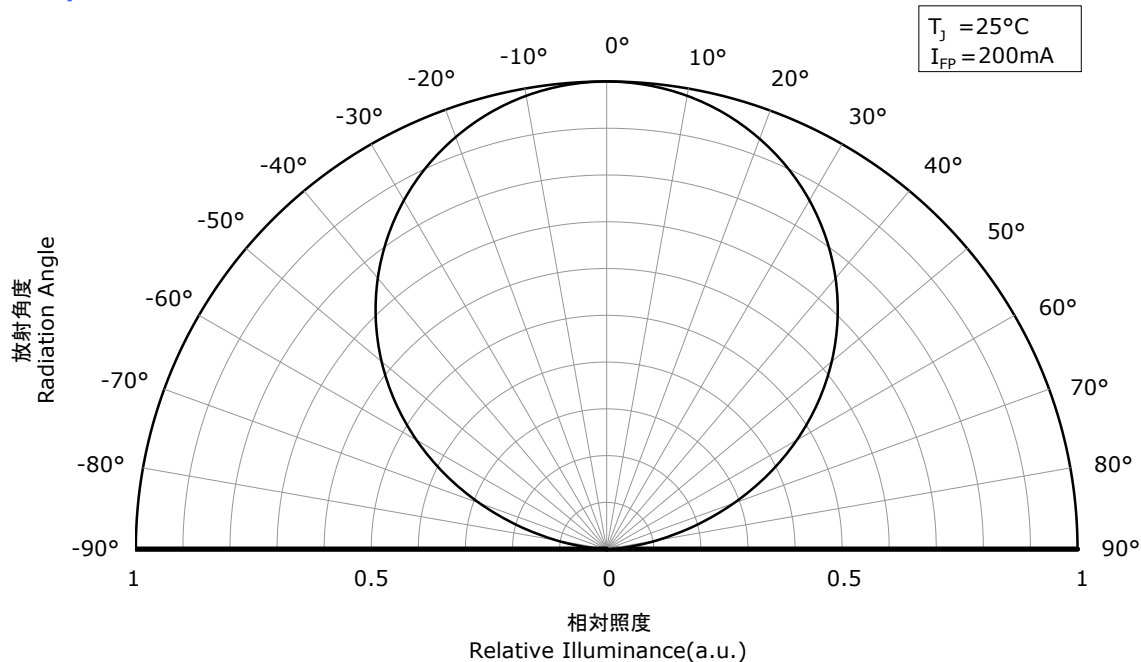
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10419A

## 発光スペクトル Spectrum



## 指向特性 Directivity



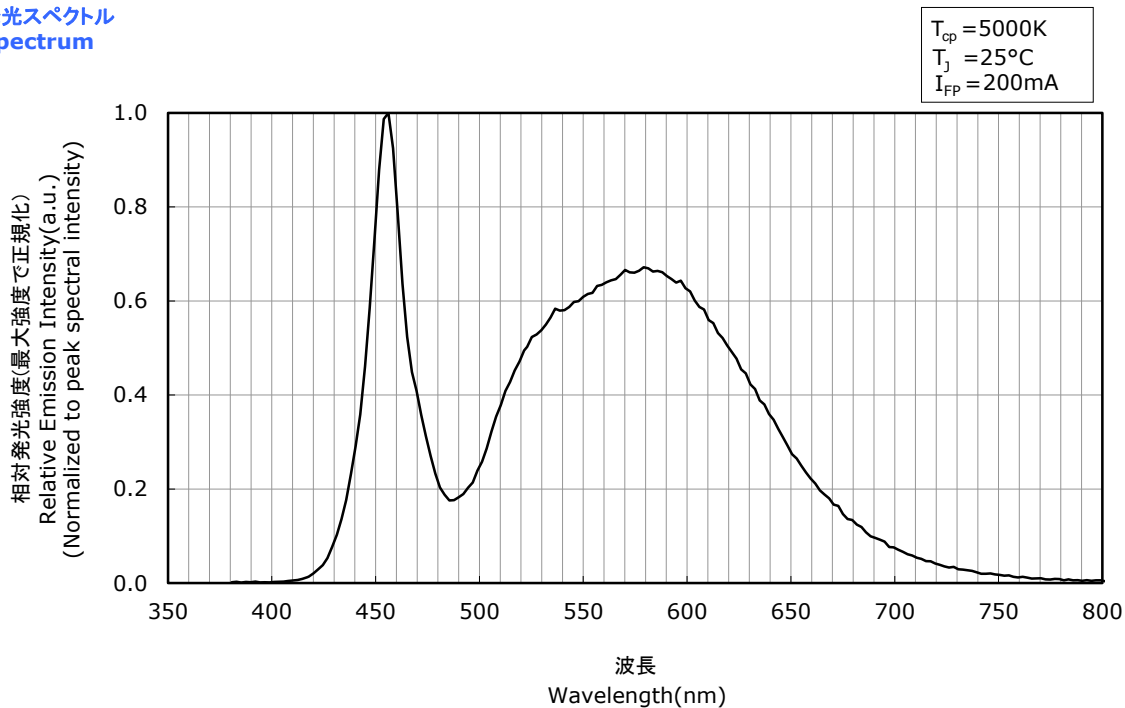
- \* 本特性は演色性ランクR9050に対応しています。  
The graphs above show the characteristics for R9050 LEDs of this product.

## OPTICAL CHARACTERISTICS

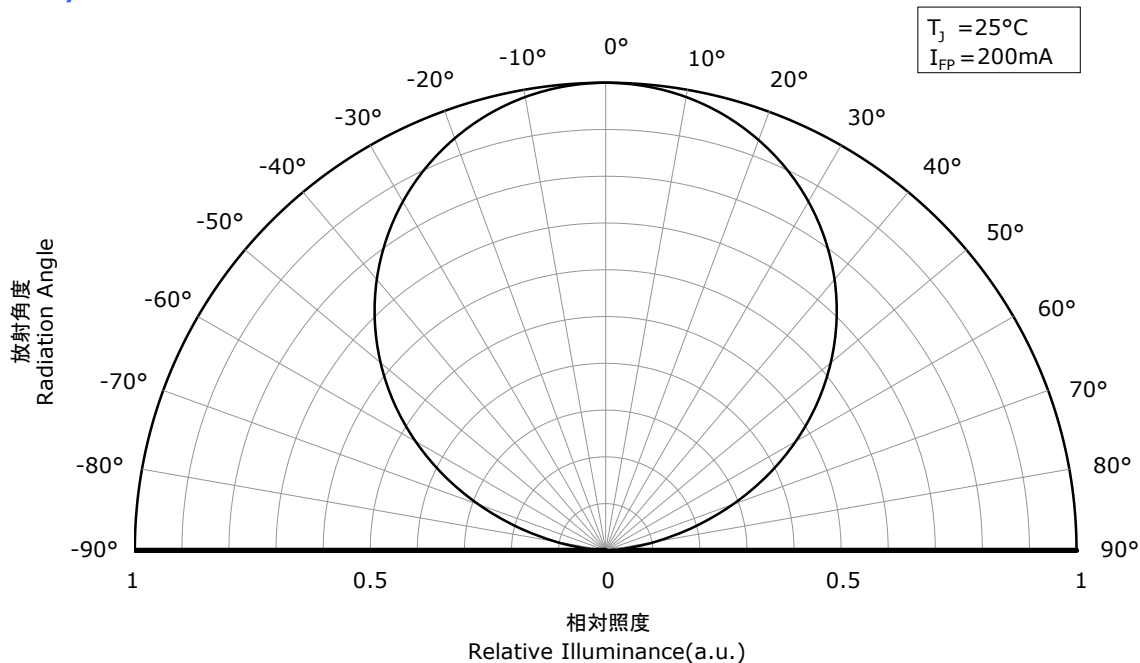
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10420A

### 発光スペクトル Spectrum



### 指向特性 Directivity



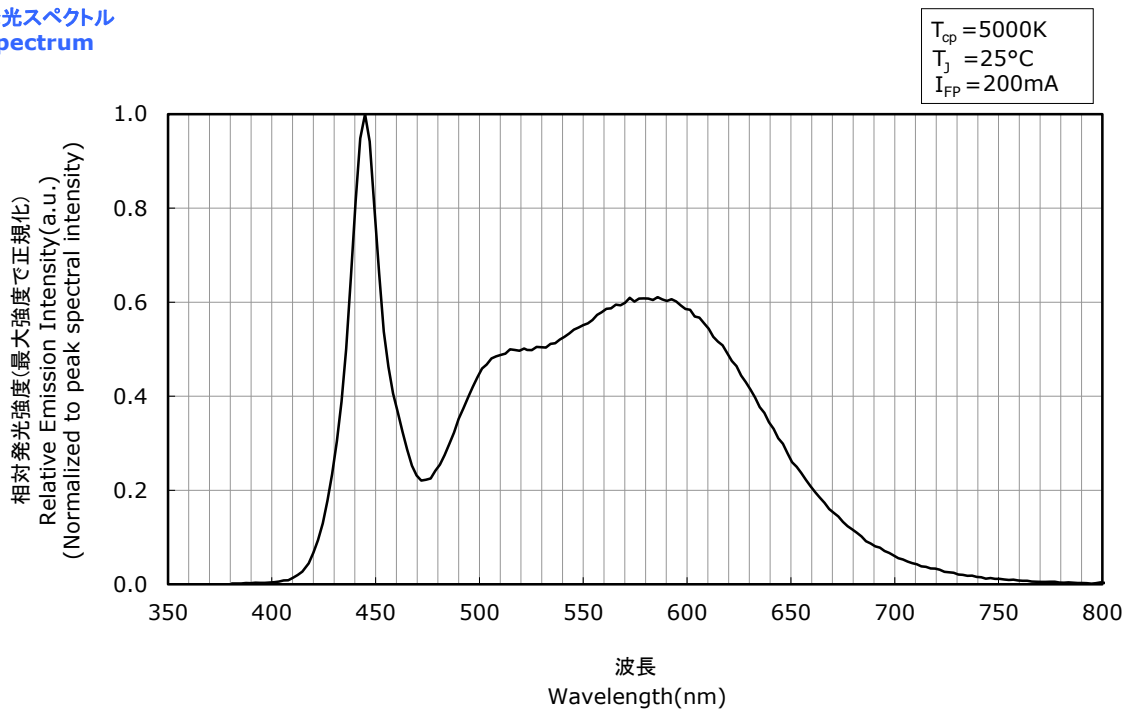
- \* 本特性は演色性ランクR70に対応しています。  
The graphs above show the characteristics for R70 LEDs of this product.

## OPTICAL CHARACTERISTICS

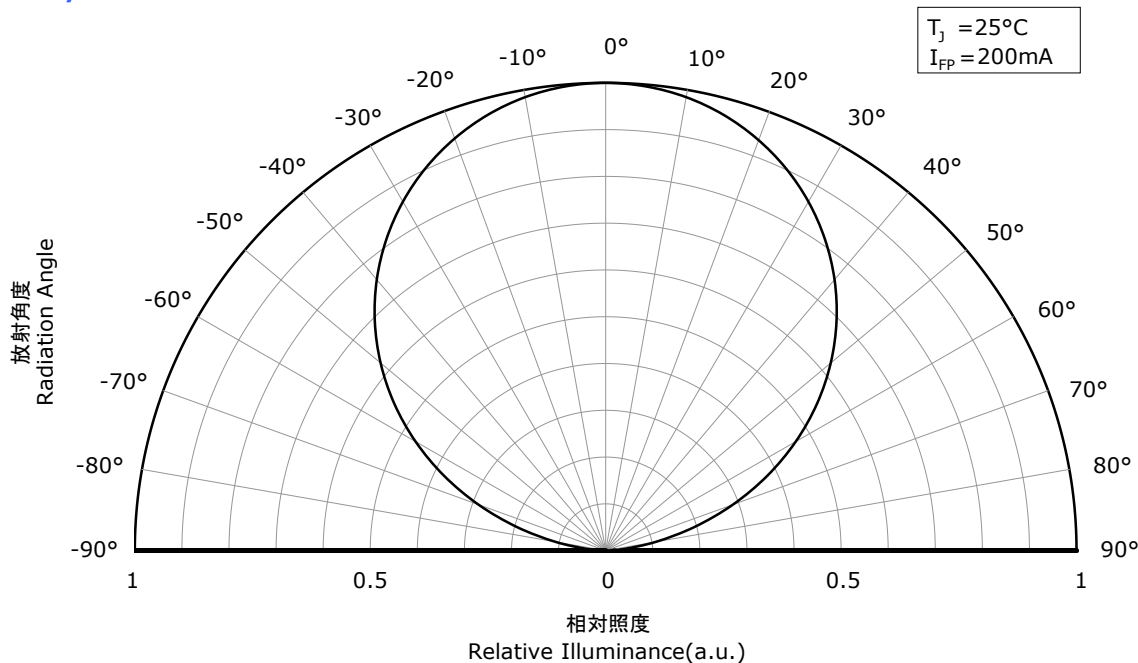
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10421A

### 発光スペクトル Spectrum



### 指向特性 Directivity



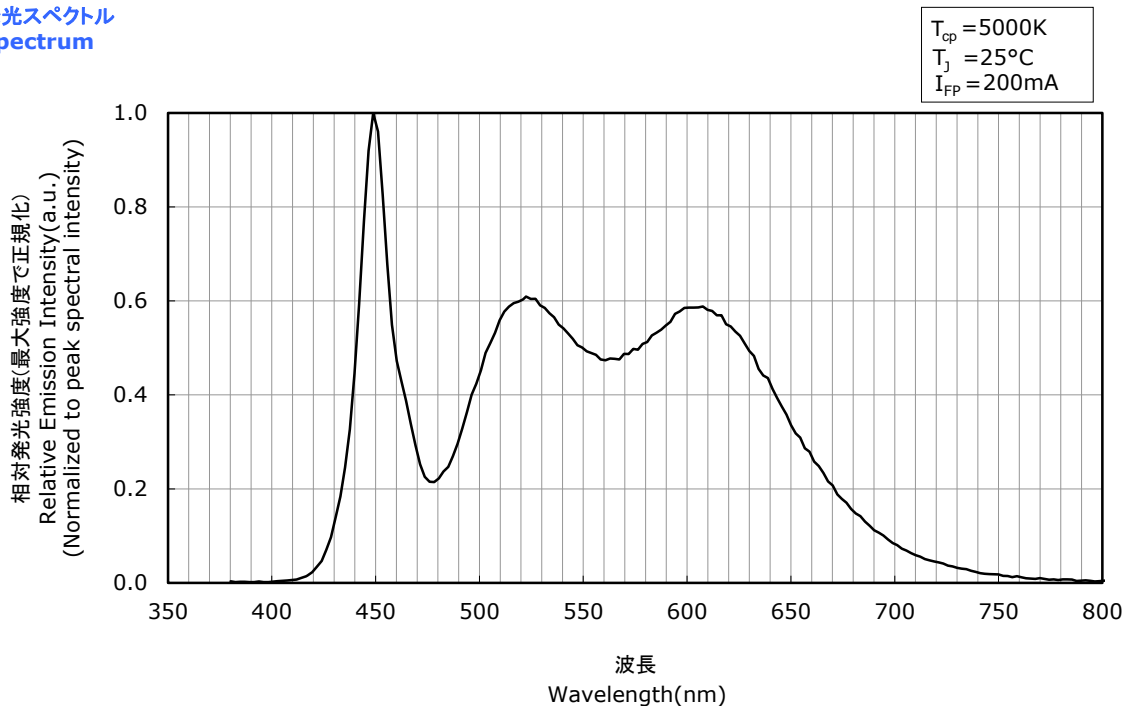
- \* 本特性は演色性ランクR8000に対応しています。  
The graphs above show the characteristics for R8000 LEDs of this product.

# OPTICAL CHARACTERISTICS

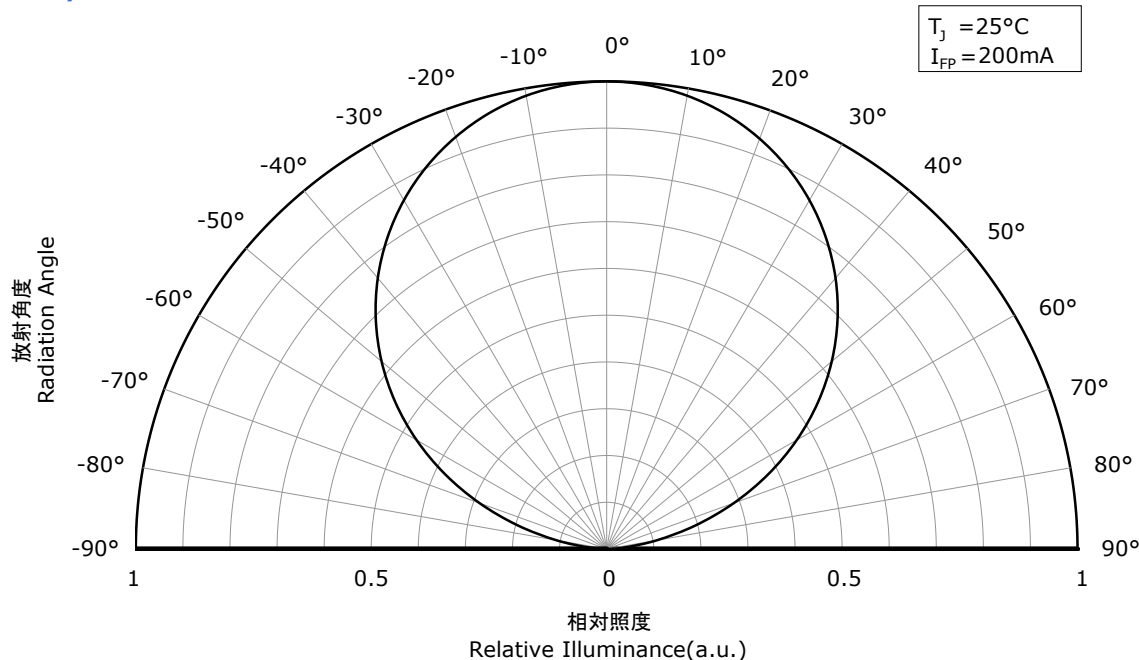
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10422A

## 発光スペクトル Spectrum



## 指向特性 Directivity



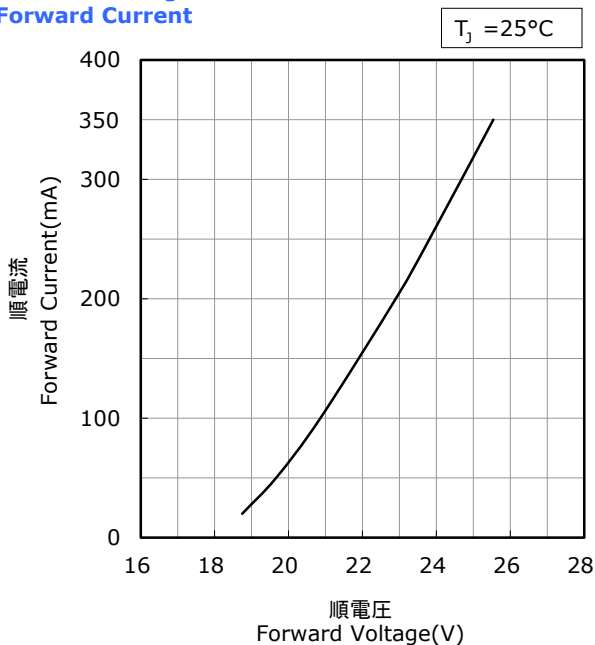
- \* 本特性は演色性ランクR9050に対応しています。  
The graphs above show the characteristics for R9050 LEDs of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

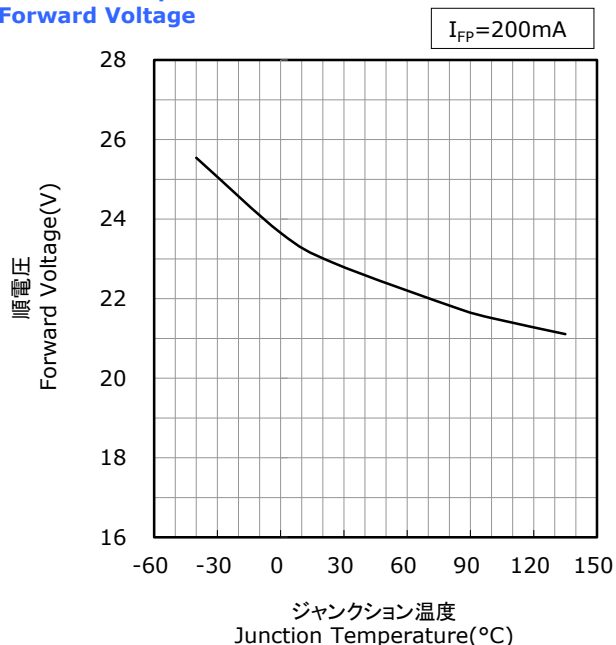
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10423A

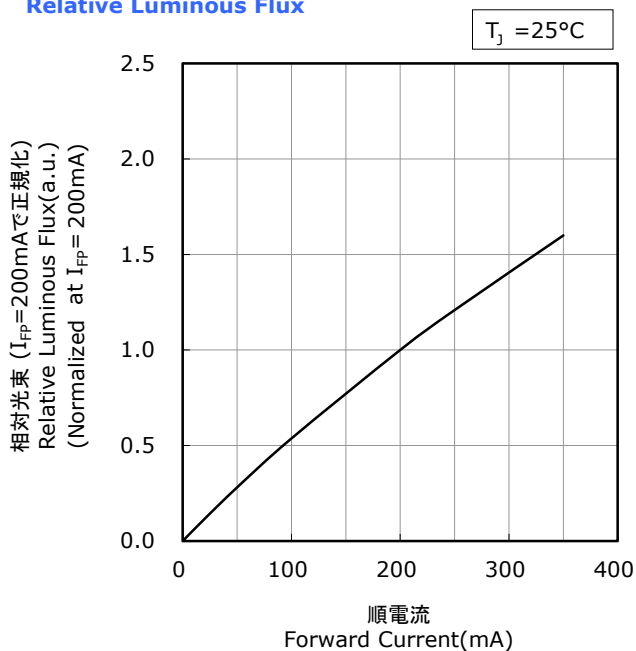
順電圧-順電流特性  
Forward Voltage vs  
Forward Current



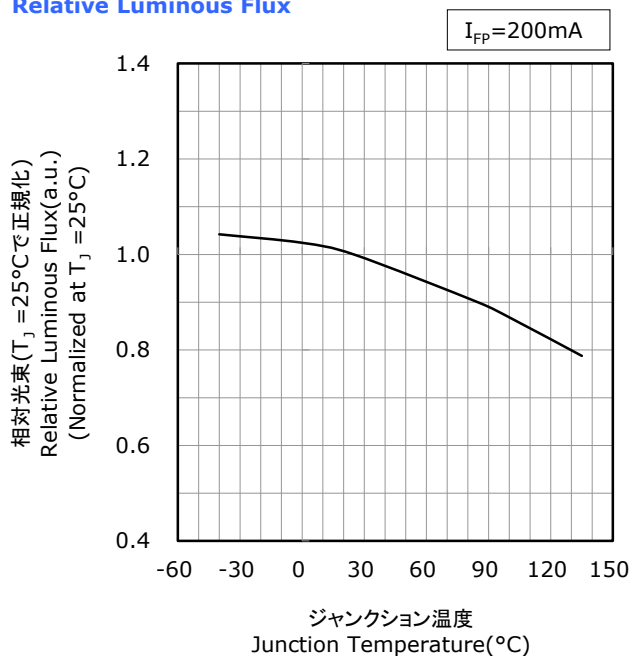
ジャンクション温度-順電圧特性  
Junction Temperature vs  
Forward Voltage



順電流-相対光束特性  
Forward Current vs  
Relative Luminous Flux



ジャンクション温度-相対光束特性  
Junction Temperature vs  
Relative Luminous Flux



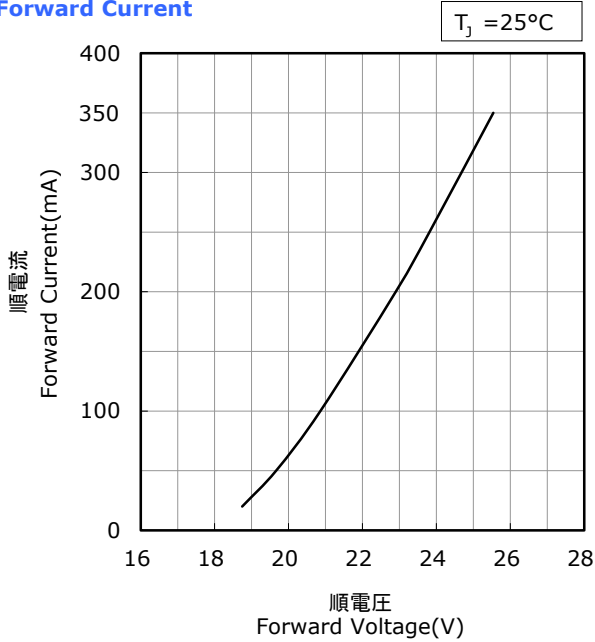
- \* 本特性は色度ランクsm27x, sm30x, sm35x, sm40x, sm45x(ランク座標範囲内の特別ランクを含む)、演色性ランクR70 に対応しています。  
The graphs above show the characteristics for sm27x, sm30x, sm35x, sm40x, sm45x, R70 LEDs, including sub-bins, of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

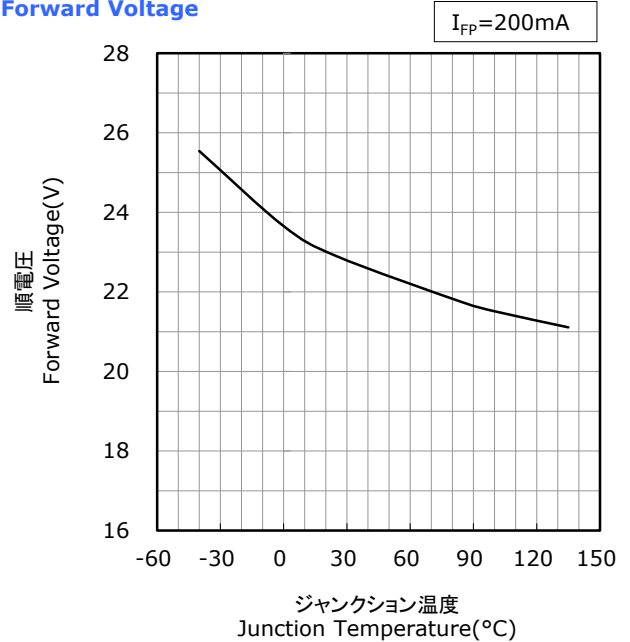
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10424A

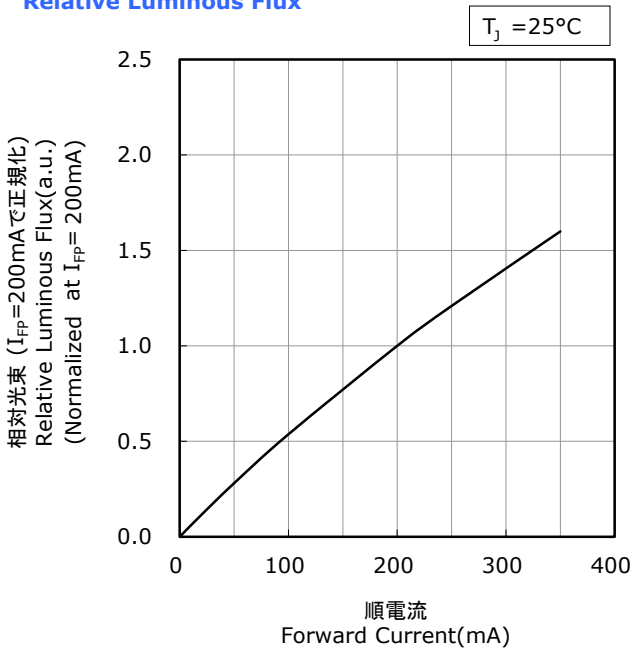
順電圧-順電流特性  
Forward Voltage vs  
Forward Current



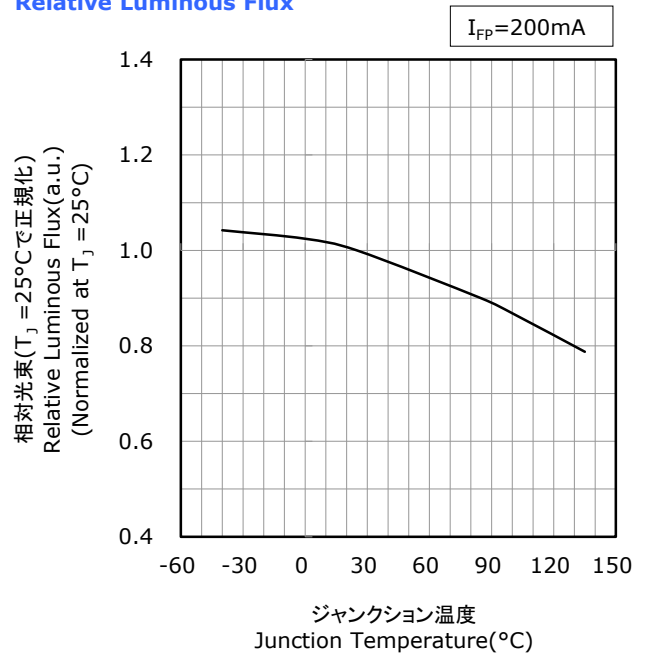
ジャンクション温度-順電圧特性  
Junction Temperature vs  
Forward Voltage



順電流-相対光束特性  
Forward Current vs  
Relative Luminous Flux



ジャンクション温度-相対光束特性  
Junction Temperature vs  
Relative Luminous Flux



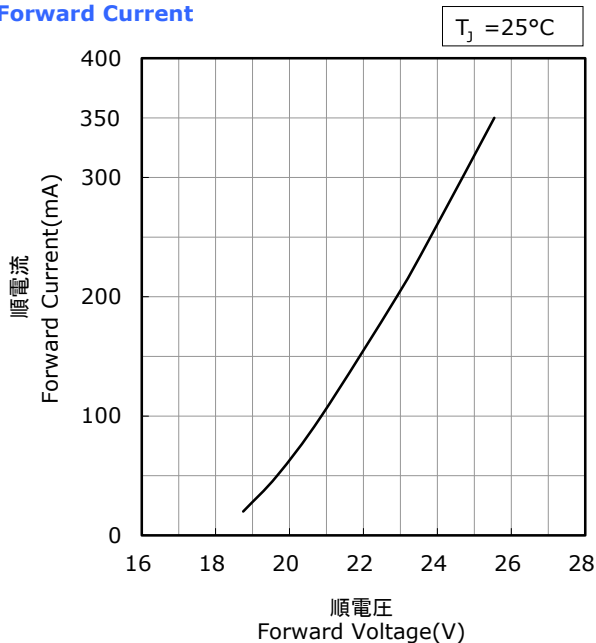
- \* 本特性は色度ランクsm20x、sm22x、sm25x、sm27x、sm30x、sm35x、sm40x、sm45x(ランク座標範囲内の特別ランクを含む)、演色性ランクR8000 に対応しています。  
The graphs above show the characteristics for sm20x, sm22x, sm25x, sm27x, sm30x, sm35x, sm40x, sm45x, R8000 LEDs, including sub-bins, of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

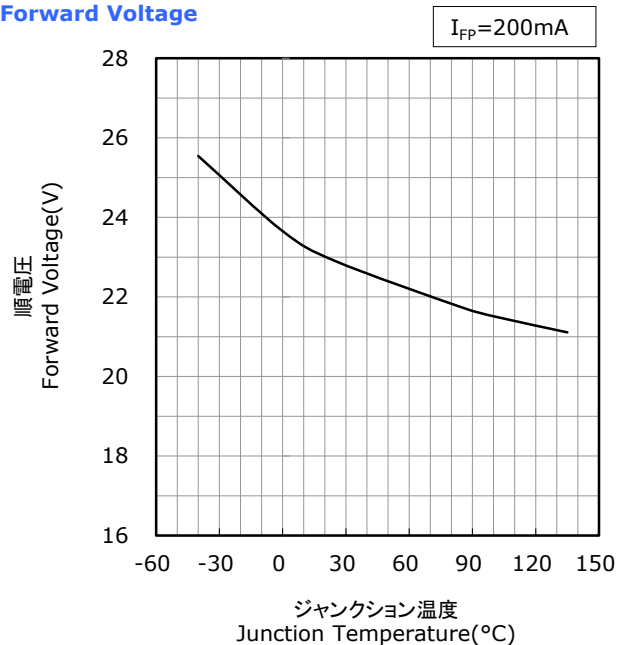
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10425A

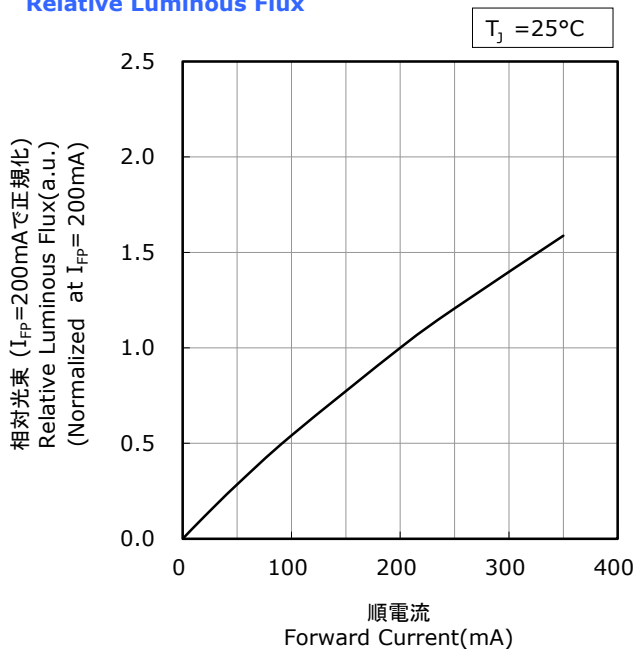
順電圧-順電流特性  
Forward Voltage vs  
Forward Current



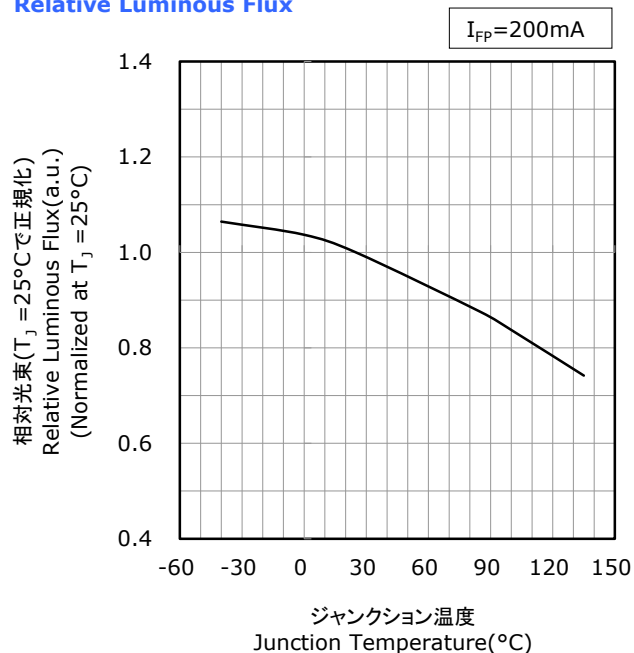
ジャンクション温度-順電圧特性  
Junction Temperature vs  
Forward Voltage



順電流-相対光束特性  
Forward Current vs  
Relative Luminous Flux



ジャンクション温度-相対光束特性  
Junction Temperature vs  
Relative Luminous Flux



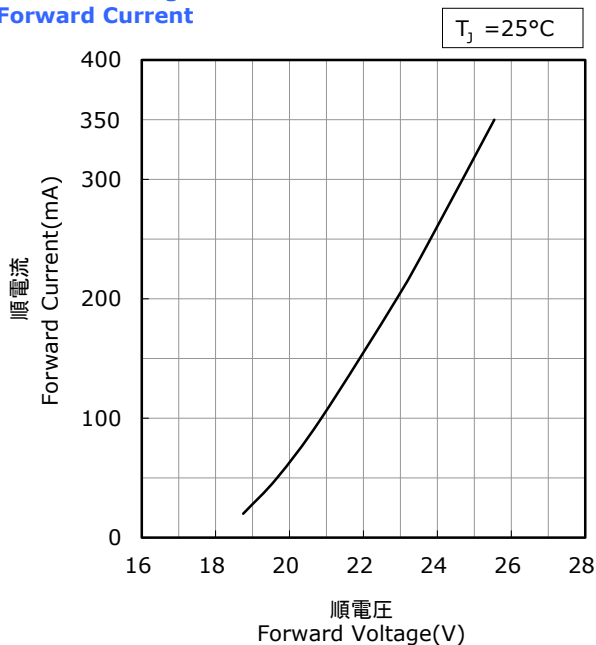
- \* 本特性は色度ランクsm27x、sm30x、sm35x、sm40x、sm45x(ランク座標範囲内の特別ランクを含む)、演色性ランクR9050 に対応しています。  
The graphs above show the characteristics for sm27x, sm30x, sm35x, sm40x, sm45x, R9050 LEDs, including sub-bins, of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

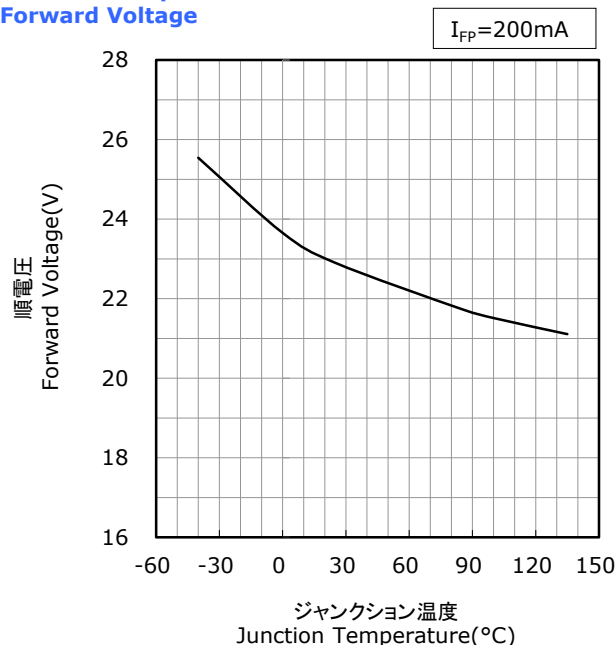
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10426A

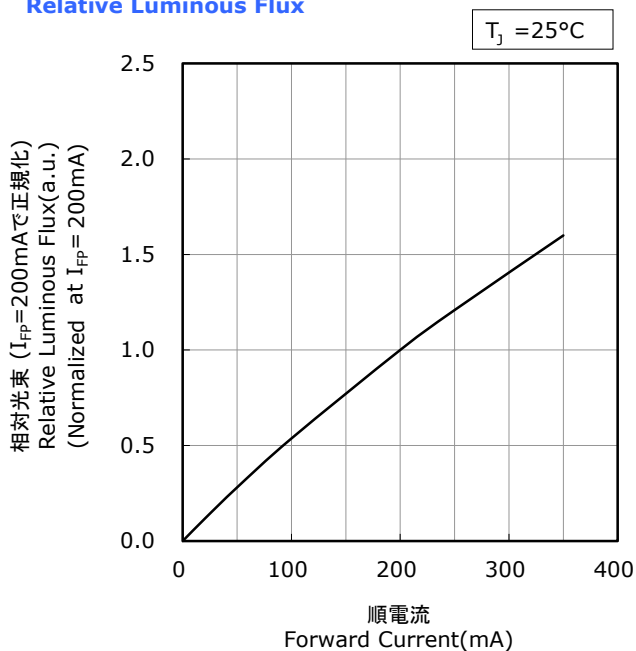
順電圧-順電流特性  
Forward Voltage vs  
Forward Current



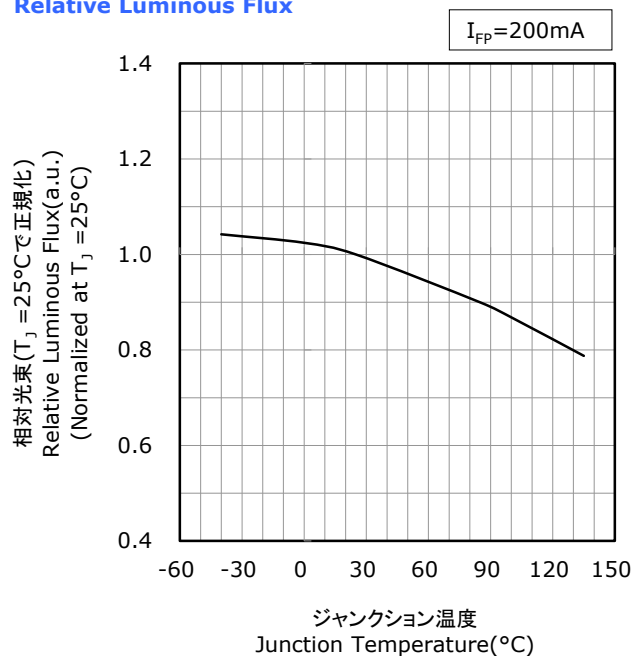
ジャンクション温度-順電圧特性  
Junction Temperature vs  
Forward Voltage



順電流-相対光束特性  
Forward Current vs  
Relative Luminous Flux



ジャンクション温度-相対光束特性  
Junction Temperature vs  
Relative Luminous Flux



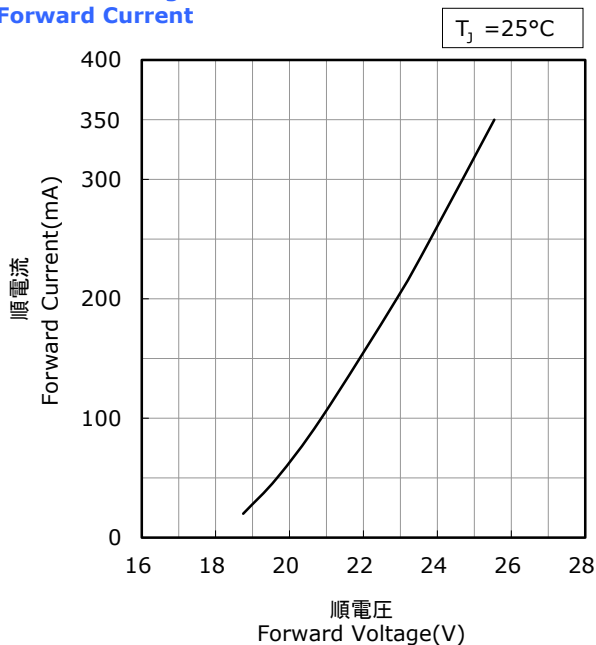
- \* 本特性は色度ランクsm65x, sm57x, sm50x(ランク座標範囲内の特別ランクを含む)、演色性ランクR70 に対応しています。  
The graphs above show the characteristics for sm65x, sm57x, sm50x, R70 LEDs, including sub-bins, of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

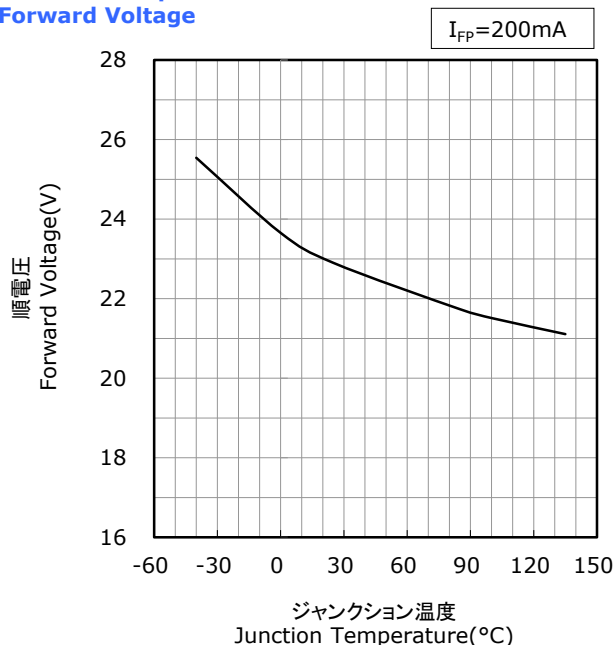
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10427A

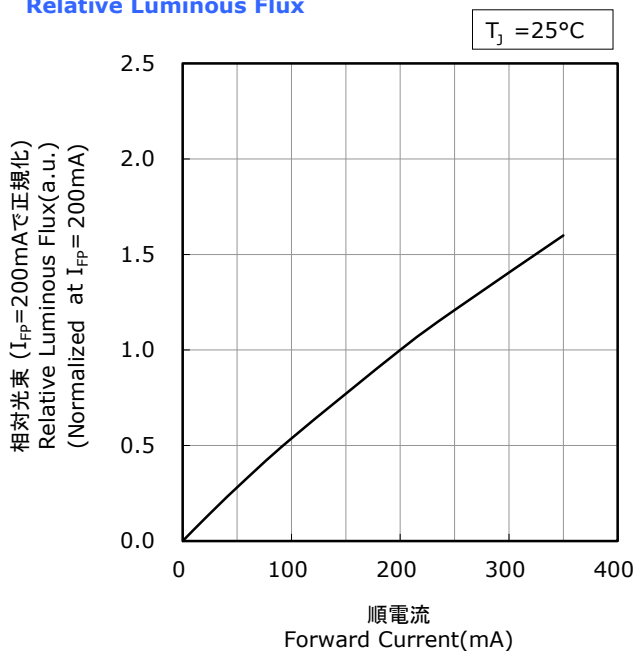
順電圧-順電流特性  
Forward Voltage vs  
Forward Current



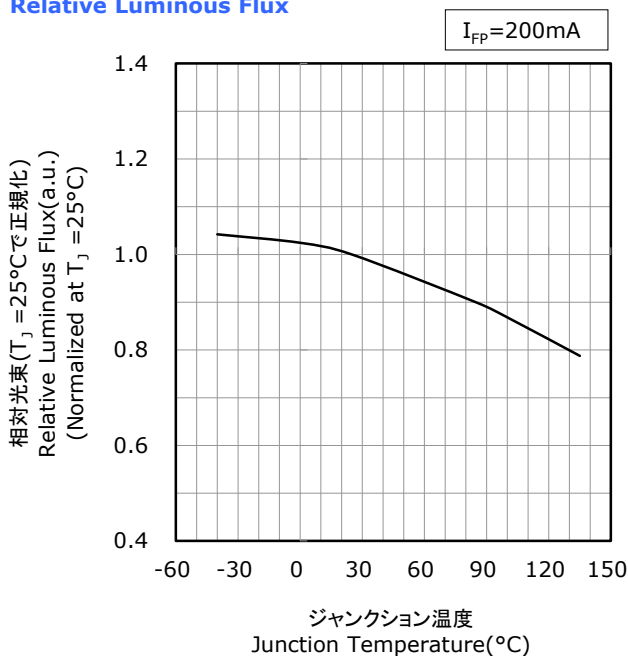
ジャンクション温度-順電圧特性  
Junction Temperature vs  
Forward Voltage



順電流-相対光束特性  
Forward Current vs  
Relative Luminous Flux



ジャンクション温度-相対光束特性  
Junction Temperature vs  
Relative Luminous Flux



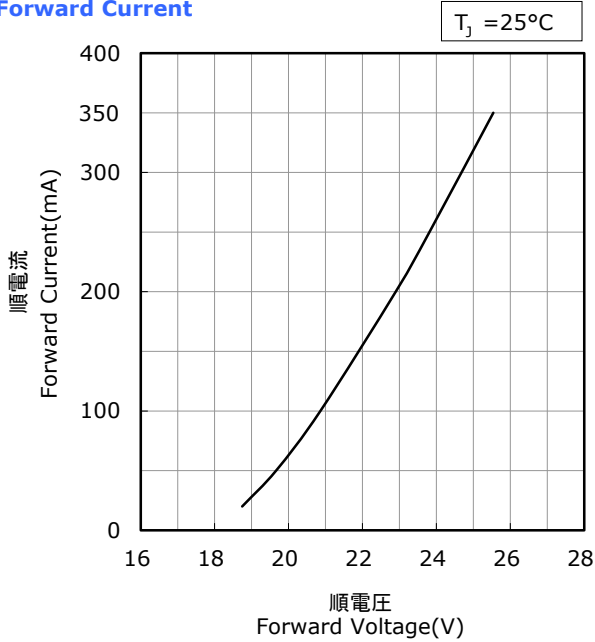
- \* 本特性は色度ランクsm65x, sm57x, sm50x(ランク座標範囲内の特別ランクを含む)、演色性ランクR8000 に対応しています。  
The graphs above show the characteristics for sm65x, sm57x, sm50x, R8000 LEDs, including sub-bins, of this product.

# FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

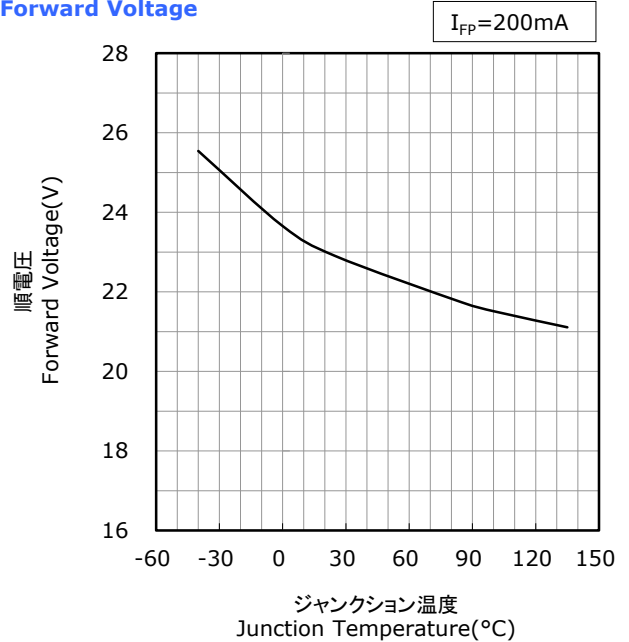
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10428A

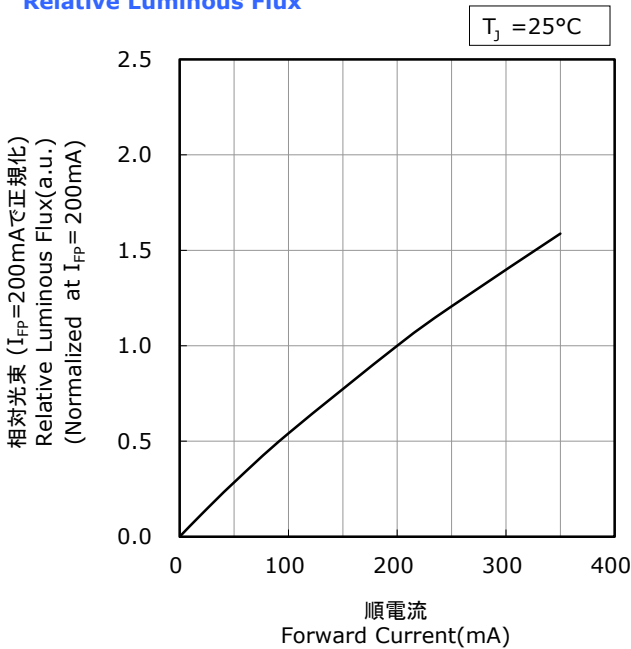
**順電圧-順電流特性**  
**Forward Voltage vs Forward Current**



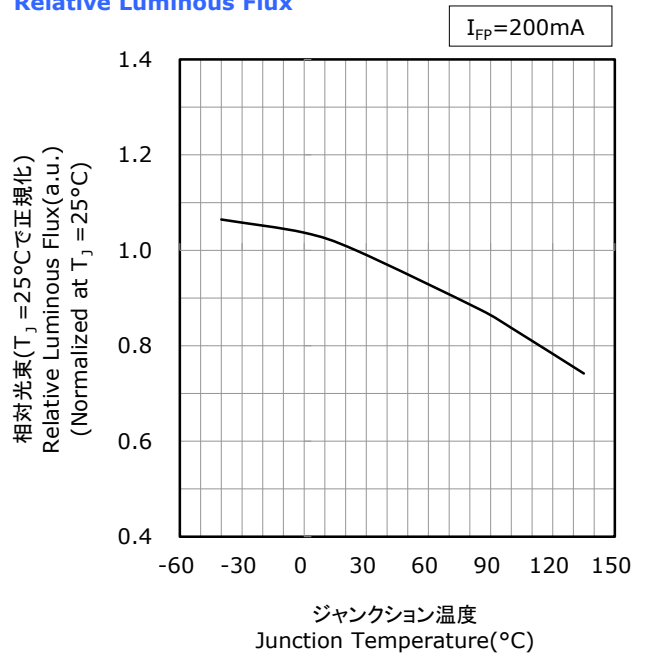
**ジャンクション温度-順電圧特性**  
**Junction Temperature vs Forward Voltage**



**順電流-相対光束特性**  
**Forward Current vs Relative Luminous Flux**



**ジャンクション温度-相対光束特性**  
**Junction Temperature vs Relative Luminous Flux**



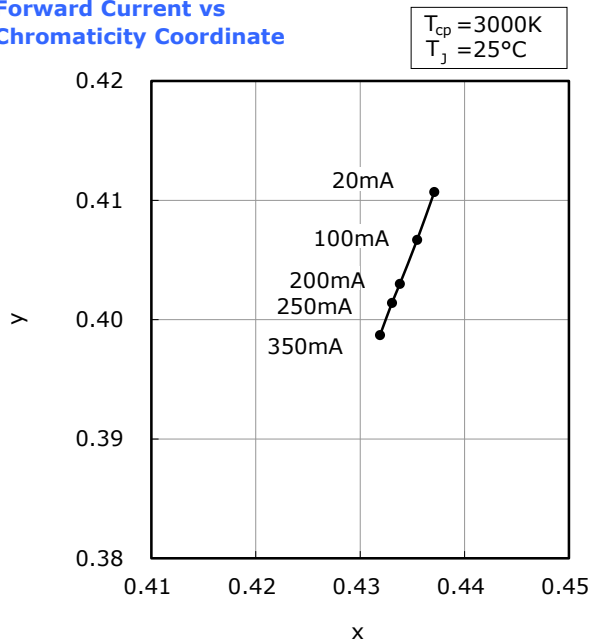
- \* 本特性は色度ランクsm50x(ランク座標範囲内の特別ランクを含む)、演色性ランクR9050 に対応しています。  
The graphs above show the characteristics for sm50x, R9050 LEDs, including sub-bins, of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

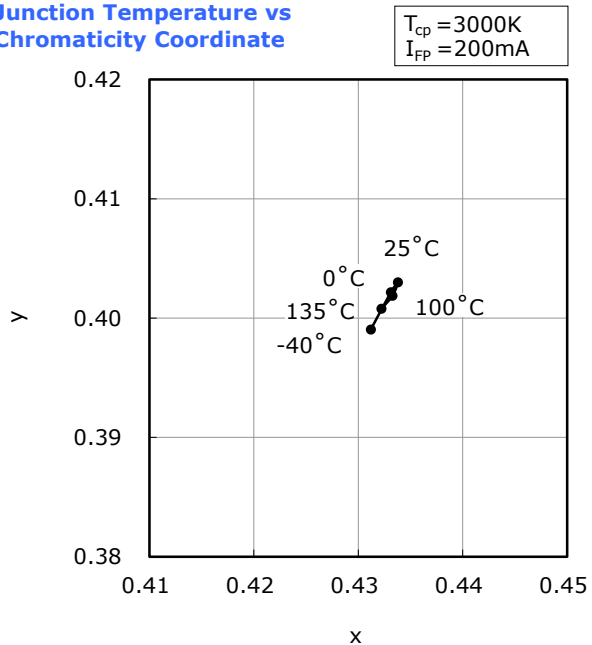
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10429A

順電流-色度 特性  
Forward Current vs  
Chromaticity Coordinate



ジャンクション温度-色度 特性  
Junction Temperature vs  
Chromaticity Coordinate



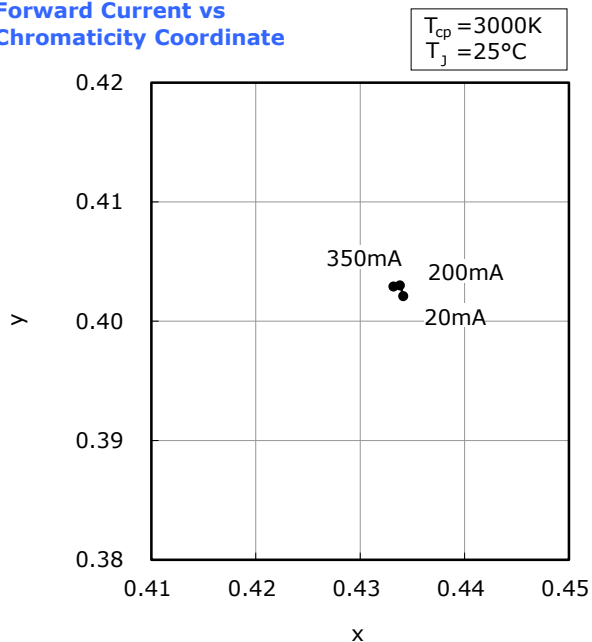
- \* 本特性は演色性ランクR70に対応しています。  
The graphs above show the characteristics for R70 LEDs of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

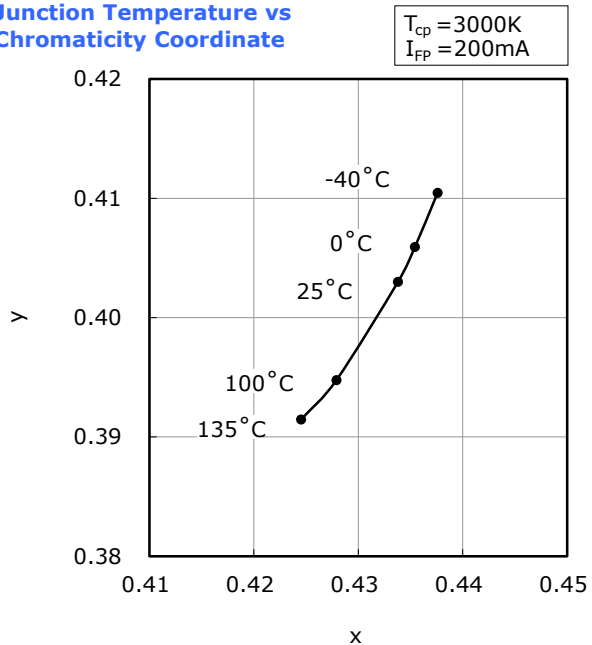
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10430A

順電流-色度 特性  
Forward Current vs  
Chromaticity Coordinate



ジャンクション温度-色度 特性  
Junction Temperature vs  
Chromaticity Coordinate

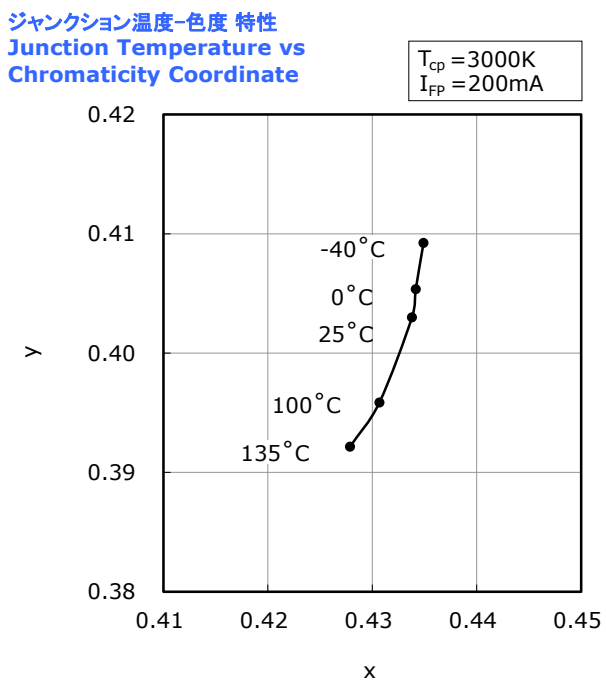
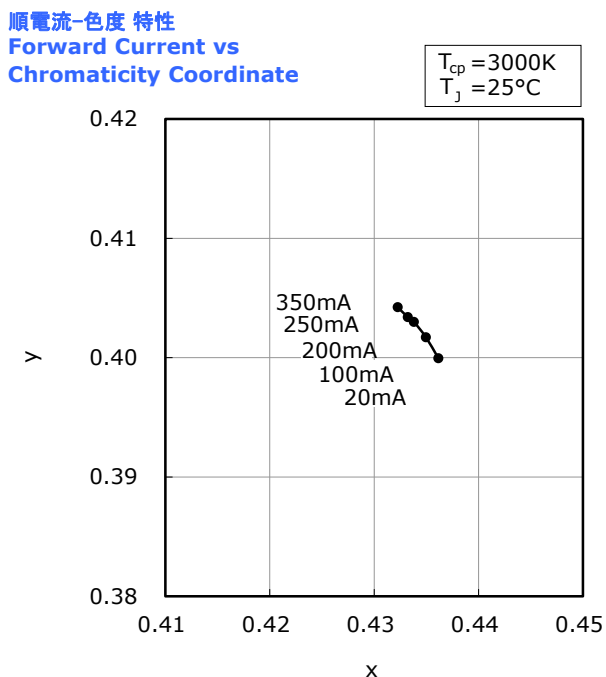


- \* 本特性は演色性ランクR8000に対応しています。  
The graphs above show the characteristics for R8000 LEDs of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10431A



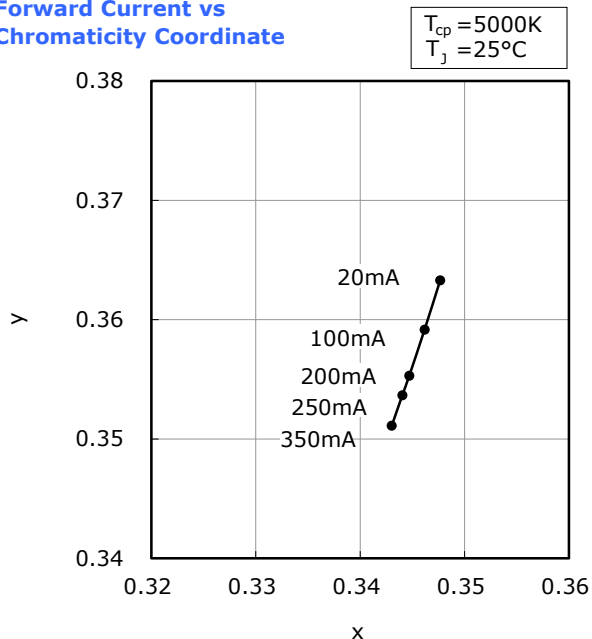
- \* 本特性は演色性ランクR9050に対応しています。  
The graphs above show the characteristics for R9050 LEDs of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

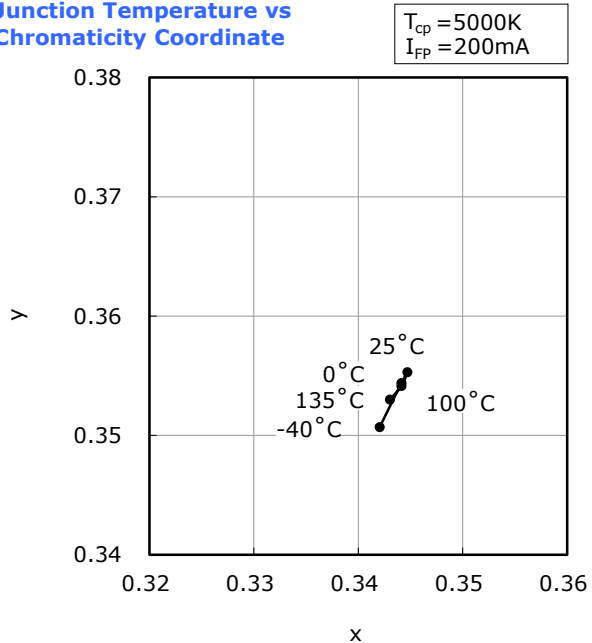
- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10432A

順電流-色度 特性  
Forward Current vs  
Chromaticity Coordinate



ジャンクション温度-色度 特性  
Junction Temperature vs  
Chromaticity Coordinate

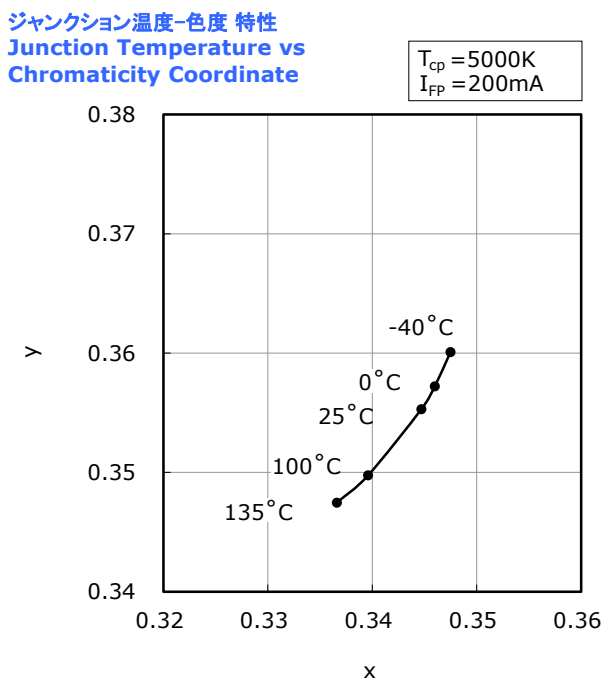
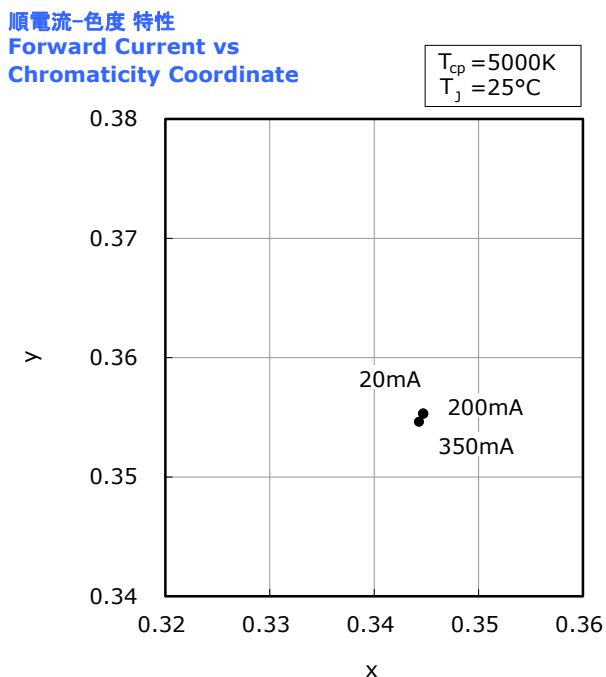


- \* 本特性は演色性ランクR70に対応しています。  
The graphs above show the characteristics for R70 LEDs of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10433A

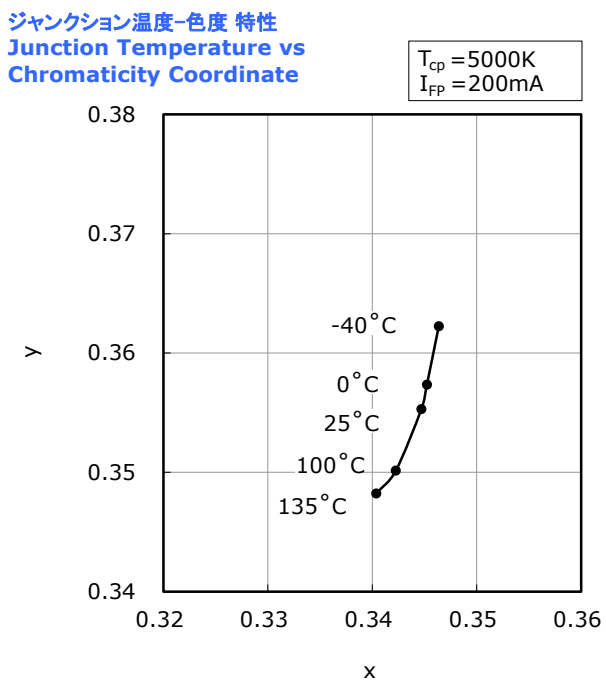
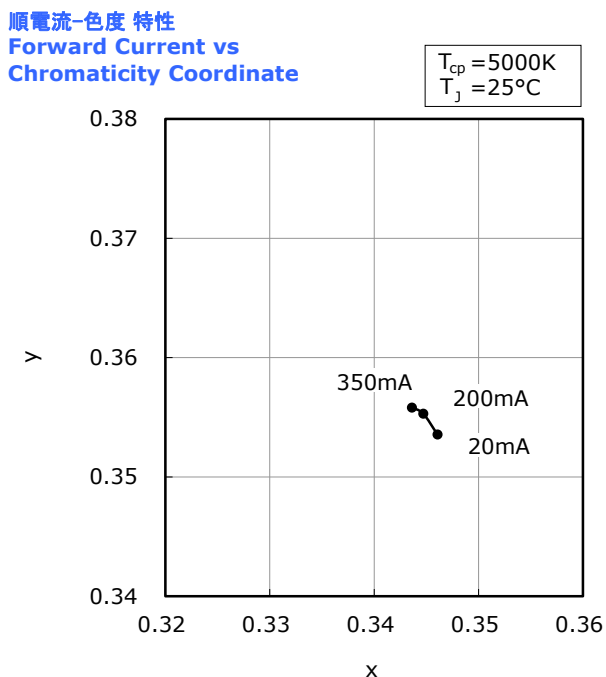


- \* 本特性は演色性ランクR8000に対応しています。  
The graphs above show the characteristics for R8000 LEDs of this product.

## FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

- \* 本特性は参考です。  
All characteristics shown are for reference only and are not guaranteed.
- \* パルス駆動により測定しています。  
The following graphs show the characteristics measured in pulse mode.

NFMW481AR  
管理番号 No. STS-DA7-10434A



- \* 本特性は演色性ランクR9050に対応しています。  
The graphs above show the characteristics for R9050 LEDs of this product.

## RELIABILITY

## (1) Tests and Results

Test	Reference Standard	Test Conditions	Test Duration	Failure Criteria #	Units Failed/Tested
Resistance to Soldering Heat (Reflow Soldering)	JEITA ED-4701 300 301	$T_{\text{slid}}=260^{\circ}\text{C}$ , 10sec, 2reflows, Precondition: $30^{\circ}\text{C}$ , 70%RH, 168hr		#1	0/22
Solderability (Reflow Soldering)	JEITA ED-4701 303 303A	$T_{\text{slid}}=245\pm 5^{\circ}\text{C}$ , 5sec, Lead-free Solder(Sn-3.0Ag-0.5Cu)		#2	0/22
Temperature Cycle	JEITA ED-4701 100 105	$-40^{\circ}\text{C}(30\text{min})\sim 25^{\circ}\text{C}(5\text{min})\sim 100^{\circ}\text{C}(30\text{min})\sim 25^{\circ}\text{C}(5\text{min})$	100cycles	#1	0/50
Moisture Resistance (Cyclic)	JEITA ED-4701 200 203	$25^{\circ}\text{C}\sim 65^{\circ}\text{C}\sim -10^{\circ}\text{C}$ , 90%RH, 24hr per cycle	10cycles	#1	0/22
High Temperature Storage	JEITA ED-4701 200 201	$T_{\text{A}}=100^{\circ}\text{C}$	1000hours	#1	0/22
Temperature Humidity Storage	JEITA ED-4701 100 103	$T_{\text{A}}=60^{\circ}\text{C}$ , RH=90%	1000hours	#1	0/22
Low Temperature Storage	JEITA ED-4701 200 202	$T_{\text{A}}=-40^{\circ}\text{C}$	1000hours	#1	0/22
Room Temperature Operating Life Condition 1		$T_{\text{A}}=25^{\circ}\text{C}$ , $I_{\text{F}}=200\text{mA}$ Test board: See NOTES below	1000hours	#1	0/22
Room Temperature Operating Life Condition 2		$T_{\text{A}}=25^{\circ}\text{C}$ , $I_{\text{F}}=250\text{mA}$ Test board: See NOTES below	500hours	#1	0/22
High Temperature Operating Life		$T_{\text{A}}=100^{\circ}\text{C}$ , $I_{\text{F}}=100\text{mA}$ Test board: See NOTES below	1000hours	#1	0/22
Temperature Humidity Operating Life		$60^{\circ}\text{C}$ , RH=90%, $I_{\text{F}}=150\text{mA}$ Test board: See NOTES below	500hours	#1	0/22
Low Temperature Operating Life		$T_{\text{A}}=-40^{\circ}\text{C}$ , $I_{\text{F}}=200\text{mA}$ Test board: See NOTES below	1000hours	#1	0/22
Vibration	JEITA ED-4701 400 403	$200\text{m/s}^2$ , 100~2000~100Hz, 4cycles, 4min, each X, Y, Z	48minutes	#1	0/22
Electrostatic Discharges	JEITA ED-4701 300 304	HBM, 2kV, 1.5k $\Omega$ , 100pF, 3pulses, alternately positive or negative		#1	0/22
Soldering Joint Shear Strength	JEITA ED-4702B 002 3	5N, 10 $\pm$ 1sec		#1	0/22

## NOTES:

- 1) Test board: Al board thickness=1.5mm, copper layer thickness=0.105mm, insulating layer thickness=0.12mm, thermal conductivity=4.5W/m·K,  $R_{\theta\text{JA}}\approx 7.3^{\circ}\text{C/W}$
- 2) Measurements are performed after allowing the LEDs to return to room temperature.

## (2) Failure Criteria

Criteria #	Items	Conditions	Failure Criteria
#1	Forward Voltage( $V_{\text{F}}$ )	$I_{\text{F}}=200\text{mA}$	>Initial value $\times 1.1$
	Luminous Flux( $\Phi_{\text{V}}$ )	$I_{\text{F}}=200\text{mA}$	<Initial value $\times 0.7$
#2	Solderability	-	Less than 95% solder coverage

## CAUTIONS

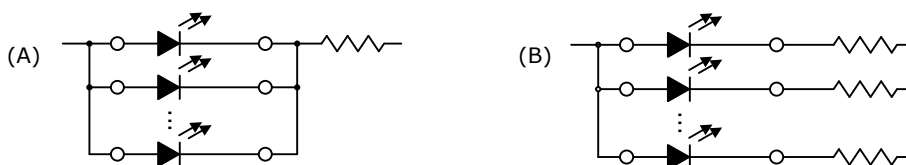
### (1) Storage

Conditions		Temperature	Humidity	Time
Storage	Before Opening Aluminum Bag	$\leq 30^{\circ}\text{C}$	$\leq 90\% \text{RH}$	Within 1 Year from Delivery Date
	After Opening Aluminum Bag	$\leq 30^{\circ}\text{C}$	$\leq 70\% \text{RH}$	$\leq 168 \text{hours}$
Baking		$65 \pm 5^{\circ}\text{C}$	-	$\geq 24 \text{hours}$

- Product complies with JEDEC MSL 3 or equivalent. See IPC/JEDEC STD-020 for moisture-sensitivity details.
- Absorbed moisture in LED packages can vaporize and expand during soldering, which can cause interface delamination and result in optical performance degradation. Products are packed in moisture-proof aluminum bags to minimize moisture absorption during transportation and storage.  
Included silica gel desiccants change from blue to red if moisture had penetrated bags.
- After opening the moisture-proof aluminum bag, the products should go through the soldering process within the range of the conditions stated above. Unused remaining LEDs should be stored with silica gel desiccants in a hermetically sealed container, preferably the original moisture-proof bags for storage.
- After the "Period After Opening" storage time has been exceeded or silica gel desiccants are no longer blue, the products should be baked. Baking should only be done once.
- Customer is advised to keep the LEDs in an airtight container when not in use. Exposure to a corrosive environment may cause the plated metal parts of the product to tarnish, which could adversely affect soldering and optical characteristics. It is also recommended to return the LEDs to the original moisture proof bags and reseal.
- After assembly and during use, silver plating can be affected by the corrosive gases emitted by components and materials in close proximity of the LEDs within an end product, and the gases entering into the product from the external atmosphere. The above should be taken into consideration when designing.  
Resin materials, in particular, may contain substances which can affect silver plating, such as halogen.
- Do not use sulfur-containing materials in commercial products. Some materials, such as seals and adhesives, may contain sulfur. The extremely corroded or contaminated plating of LEDs might cause an open circuit. Silicone rubber is recommended as a material for seals. Bear in mind, the use of silicones may lead to silicone contamination of electrical contacts inside the products, caused by low molecular weight volatile siloxane.
- To prevent water condensation, please avoid large temperature and humidity fluctuations for the storage conditions.
- Do not store the LEDs in a dusty environment.
- Do not expose the LEDs to direct sunlight and/or an environment where the temperature is higher than normal room temperature.

### (2) Directions for Use

- When designing a circuit, the current through each LED must not exceed the Absolute Maximum Rating. Operating at a constant current per LED is recommended. In case of operating at a constant voltage, Circuit B is recommended. If the LEDs are operated with constant voltage using Circuit A, the current through the LEDs may vary due to the variation in Forward Voltage characteristics of the LEDs.



- This product should be operated using forward current. Ensure that the product is not subjected to either forward or reverse voltage while it is not in use. In particular, subjecting it to continuous reverse voltage may cause migration, which may cause damage to the LED die. When used in displays that are not used for a long time, the main power supply should be switched off for safety.
- It is recommended to operate the LEDs at a current greater than 10% of the sorting current to stabilize the LED characteristics.
- Ensure that excessive voltages such as lightning surges are not applied to the LEDs.
- For outdoor use, necessary measures should be taken to prevent water, moisture and salt air damage.

### (3) Handling Precautions

- Do not handle the LEDs with bare hands as it will contaminate the LED surface and may affect the optical characteristics: it might cause the LED to be deformed and/or the wire to break, which will cause the LED not to illuminate.  
The lead could also cause an injury.
- When handling the product with tweezers, be careful not to apply excessive force to the resin.  
Otherwise, The resin can be cut, chipped, delaminate or deformed, causing wire-bond breaks and catastrophic failures.
- Dropping the product may cause damage.
- Do not stack assembled PCBs together. Failure to comply can cause the resin portion of the product to be cut, chipped, delaminated and/or deformed. It may cause wire to break, leading to catastrophic failures.

### (4) Design Consideration

- PCB warpage after mounting the products onto a PCB can cause the package to break.  
The LED should be placed in a way to minimize the stress on the LEDs due to PCB bow and twist.
- The position and orientation of the LEDs affect how much mechanical stress is exerted on the LEDs placed near the score lines.  
The LED should be placed in a way to minimize the stress on the LEDs due to board flexing.
- Board separation must be performed using special jigs, not using hands.
- Volatile organic compounds that have been released from materials present around the LEDs (e.g. housing, packing, adhesive, secondary lens, lens cover, etc.) may penetrate the LED lens and/or encapsulating resin.  
If the LEDs are being used in a hermetically sealed environment, these volatile compounds can discolor after being exposed to heat and/or photon energy and it may greatly reduce the LED light output and/or cause a color shift.  
In this case, ventilating the environment may improve the reduction in light output and/or color shift.  
Perform a light-up test of the chosen application for optical evaluation to ensure that there are no issues, especially if the LEDs are planned to be used in a hermetically sealed environment.

### (5) Electrostatic Discharge (ESD)

- The products are sensitive to static electricity or surge voltage. ESD can damage a die and its reliability.  
When handling the products, the following measures against electrostatic discharge are strongly recommended:
  - Eliminating 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 tools, jigs and machines that are being used are properly grounded and that proper grounding techniques are used in work areas. For devices/equipment that mount the LEDs, protection against surge voltages should also be used.
- If tools or equipment contain insulating materials such as glass or plastic, the following measures against electrostatic discharge are strongly recommended:
  - Dissipating static charge with conductive materials
  - Preventing charge generation with moisture
  - Neutralizing the charge with ionizers
- The customer is advised to check if the LEDs are damaged by ESD when performing the characteristics inspection of the LEDs in the application.  
Damage can be detected with a forward voltage measurement or a light-up test at low current ( $\leq 1\text{mA}$ ).
- ESD damaged LEDs may have current flow at a low voltage or no longer illuminate at a low current.  
Failure Criteria:  $V_F < 14.0\text{V}$  at  $I_F = 0.5\text{mA}$

## (6) Thermal Management

- Proper thermal management is an important when designing products with LEDs. LED die temperature is affected by PCB thermal resistance and LED spacing on the board. Please design products in a way that the LED die temperature does not exceed the maximum Junction Temperature ( $T_J$ ).
- Drive current should be determined for the surrounding ambient temperature ( $T_A$ ) to dissipate the heat from the product.
- The following equations can be used to calculate the LED temperature (i.e.  $T_J$ ) once the saturation temperature at the junction has been reached.

$$1) T_J = T_A + R_{\theta JA} \cdot W \quad 2) T_J = T_S + R_{\theta JS} \cdot W$$

\* $T_J$ =LED junction temperature: °C

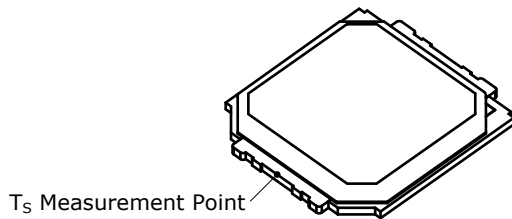
$T_A$ =Ambient temperature: °C

$T_S$ =Soldering temperature (cathode side): °C

$R_{\theta JA}$ =Thermal resistance from junction to ambient: °C/W

$R_{\theta JS}$ =Thermal resistance from junction to  $T_S$  measurement point: °C/W

$W$ =Input power( $I_F \times V_F$ ): W



## (7) Cleaning

- The LEDs should not be cleaned with water, benzene, and/or thinner.
- If required, isopropyl alcohol (IPA) should be used. Other solvents may cause premature failure to the LEDs due to the damage to the resin portion. The effects of such solvents should be verified prior to use. In addition, the use of CFCs such as Freon is heavily regulated.
- When dust and/or dirt adheres to the LEDs, soak a cloth with Isopropyl alcohol (IPA), then squeeze it before wiping the LEDs.
- Ultrasonic cleaning is not recommended since it may have adverse effects on the LEDs depending on the ultrasonic power and how LED is assembled. If ultrasonic cleaning must be used, the customer is advised to make sure the LEDs will not be damaged prior to cleaning.

## (8) Eye Safety

- In 2006, the International Electrical Commission (IEC) published IEC 62471:2006 Photobiological safety of lamps and lamp systems, which added LEDs in its scope. On the other hand, the IEC 60825-1:2007 laser safety standard removed LEDs from its scope. However, please be advised that some countries and regions have adopted standards based on the IEC laser safety standard IEC 60825-1:20112001, which still includes LEDs in its scope. Most of Nichia's LEDs can be classified as belonging into either the Exempt Group or Risk Group 1. High-power LEDs, that emit light containing blue wavelengths, may be classified as Risk Group 2. Please proceed with caution when viewing directly any LEDs driven at high current, or viewing LEDs with optical instruments which may greatly increase the damages to your eyes.
- Viewing a flashing light may cause eye discomfort. When incorporating the LED into your product, please be careful to avoid adverse effects on the human body caused by light stimulation.

## (9) Miscellaneous

- Nichia warrants that the discrete LEDs will meet the requirements/criteria as detailed in the Reliability section within this specification. If the LEDs are used under conditions/environments deviating from or inconsistent with those described in this specification, the resulting damage and/or injuries will not be covered by this warranty.
- Nichia warrants that the discrete LEDs manufactured and/or supplied by Nichia will meet the requirements/criteria as detailed in the Reliability section within this specification; it is the customer's responsibility to perform sufficient verification prior to use to ensure that the lifetime and other quality characteristics required for the intended use are met.
- The applicable warranty period is one year from the date that the LED is delivered. In the case of any incident that appears to be in breach of this warranty, the local Nichia sales representative should be notified to discuss instructions on how to proceed while ensuring that the LED in question is not disassembled or removed from the PCB if it has been attached to the PCB. If a breach of this warranty is proved, Nichia will provide the replacement for the non-conforming LED or an equivalent item at Nichia's discretion. FOREGOING ARE THE EXCLUSIVE REMEDIES AVAILABLE TO THE CUSTOMER IN RESPECT OF THE BREACH OF THE WARRANTY CONTAINED HEREIN, AND IN NO EVENT SHALL NICHIA BE RESPONSIBLE FOR ANY INDIRECT, INCIDENTAL OR CONSEQUENTIAL LOSSES AND/OR EXPENSES (INCLUDING LOSS OF PROFIT) THAT MAY BE SUFFERED BY THE CUSTOMER ARISING OUT OF A BREACH OF THE WARRANTY.
- NICHIA DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
- This LED is intended to be used for general lighting, household appliances, electronic devices (e.g. mobile communication devices); it is not designed or manufactured for use in applications that require safety critical functions (e.g. aircraft, automobiles, combustion equipment, life support systems, nuclear reactor control system, safety devices, spacecraft, submarine repeaters, traffic control equipment, trains, vessels, etc.). If the LEDs are planned to be used for these applications, unless otherwise detailed in the specification, Nichia will neither guarantee that the LED is fit for that purpose nor be responsible for any resulting property damage, injuries and/or loss of life/health.  
This LED does not comply with ISO/TS 16949 and is not intended for automotive applications.
- The customer will not reverse engineer, disassemble or otherwise attempt to extract knowledge/design information from the LED.
- All copyrights and other intellectual property rights in this specification in any form are reserved by Nichia or the right holders who have granted Nichia permission to use the content. Without prior written permission from Nichia, no part of this specification may be reproduced in any form or by any means.
- Both the customer and Nichia will agree on the official specifications for the supplied LEDs before any programs are officially launched. Without this agreement in writing (i.e. Customer Specific Specification), changes to the content of this specification may occur without notice (e.g. changes to the foregoing specifications and appearance, discontinuation of the LEDs, etc.).