Light Emitting Diode

Heat Dissipation Performance of the Nichia NVSxx19C Series LEDs at the Module Level

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The Nichia part numbers NVSx119C and NVSx219C 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

Nichia's NVSxx19C series LEDs offer two different types of electrode designs: LEDs with one cathode and one anode electrode (i.e. NVSx119C) and LEDs with an electrically isolated die heat sink in addition to these two electrodes (i.e. NVSx219C). The thermal resistances ($R_{\theta JS}$) from the LED die to the T_S measurement point are the same for both of those types. However, the LED type chosen for the design of the module (i.e. electrodes/heat sink pad on the back of the LED package) and/or the soldering pad pattern of the printed circuit board (PCB) may cause the thermal path to change causing a difference in the heat dissipation.

Nichia presumes that the NVSxx19C series LEDs will be used for applications that are operated at high currents. When the LED is operated at a high current, it produces a large amount of heat; if this causes the LED temperature (T_J) to increase, it may cause issues (e.g. reduction in the luminous flux according to the LED temperature characteristics). Ensure that when designing the PCB and the luminaire, there are no issues with the thermal designs for the chosen application.

This application note provides the results of the evaluation of the heat dissipation capabilities of the NVSxx19C series LEDs at the module level with an emphasis on the difference in the LED electrode configuration between the NVSx219C and NVSx119C LEDs.

2. Difference in the Electrode Configurations

As mentioned in the Overview, there is a difference in the electrode configuration between these models: the NVSx219C LEDs have a die heat sink that is electrically isolated from both the anode electrode and cathode electrode and the NVSx119C LEDs do not have a die heat sink. This is the only difference that exists between these models, the other parts/materials used are the same.
Refer to Figure 1 for the common appearance of the NVSxx19C series LEDs, and Figures 2 and 3 for the electrode configurations of the NVSx119C and NVSx219C LEDs.

Figure 1. Appearance of the NVSxx19C series LEDs

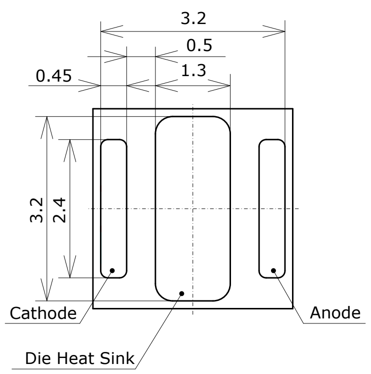


Figure 2. Electrode Configuration of the NVSx219C LEDs

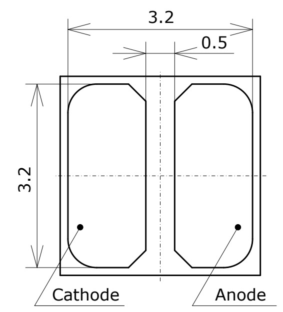


Figure 3. Electrode Configuration of the NVSx119C LEDs

When the LED is operated, it produces heat at the LED die. This heat is conducted to the LED ceramic substrate and then to the PCB (i.e. the copper layer) via the electrodes, spreading over the PCB. For the NVSx219C LEDs, heat is conducted to the PCB (i.e. the copper layer) via the cathode electrode, die heat sink, and anode electrode; for the NVSx119C LEDs, it is conducted via the cathode and anode electrodes.
Refer to Figure 4 for the NVSx219C LEDs' thermal path from the LED die to the PCB and Figure 5 for the NVSx119C LEDs' thermal path.

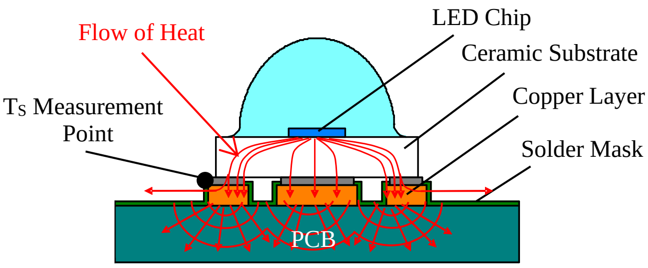


Figure 4. Thermal Path of the NVSx219C LEDs

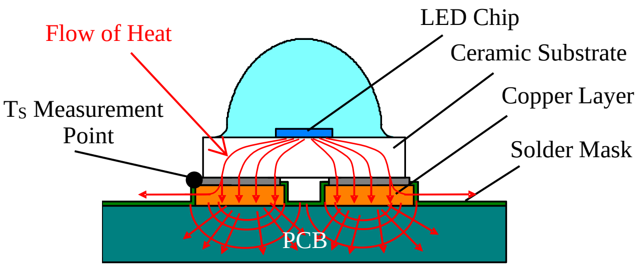


Figure 5. Thermal Path of the NVSx119C LEDs

3. Evaluation of the Heat Dissipation Capabilities

3.1 Evaluation by PCB Material and Heat Sink Size

3.1.1 Evaluation Method/Conditions

To evaluate the heat dissipation at the module level by PCB copper layer/LED electrode designs, Nichia has designed PCB layouts/modules specifically for this evaluation, each with 24 LEDs of either NVSx119C LEDs or NVSx219C LEDs. The details of the evaluation methods/conditions are as follows:

- There is no difference in the specifications (e.g. PCB materials, dimensions) between the PCBs used for the evaluation, except for the PCB copper layer patterns.
- Two different copper layer patterns (i.e. Pattern 1 and Pattern 2) were used for NVSx219C LEDs and one copper layer pattern (i.e. Pattern 3) was used for NVSx119C LEDs (See Table 1 for the PCB layout).
- To reproduce typical operating conditions used for actual applications, three different heat sinks (i.e. Rjhs ≈ 1.1°C/W, Rjhs ≈ 0.7°C /W and Rjhs ≈ 0.45°C /W) were used with the aluminum core PCBs.
- The input currents to the test modules (i.e. I_F = 700mA, I_F = 1200mA, and I_F = 1800mA) were determined according to the heat dissipation capability of the heat sink being used (See Table 2 for the heat sinks and aluminum core PCBs used).
- Four LEDs were chosen from the 24 LEDs per aluminum core PCB. Once the saturation temperature had been reached for those four LEDs, they were measured at the T_S measurement point (See Table 1).
- To evaluate the effect of the temperature saturation on the module's luminous flux (i.e. reduction in the luminous flux), measurements were performed immediately after the LEDs were turned on and once the saturation temperature at the T_S measurement point had been reached.

Table 1. Evaluation Conditions

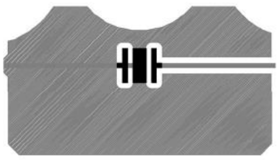
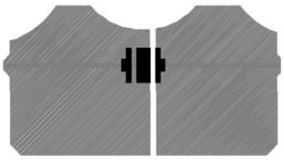
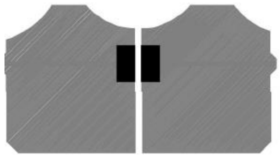
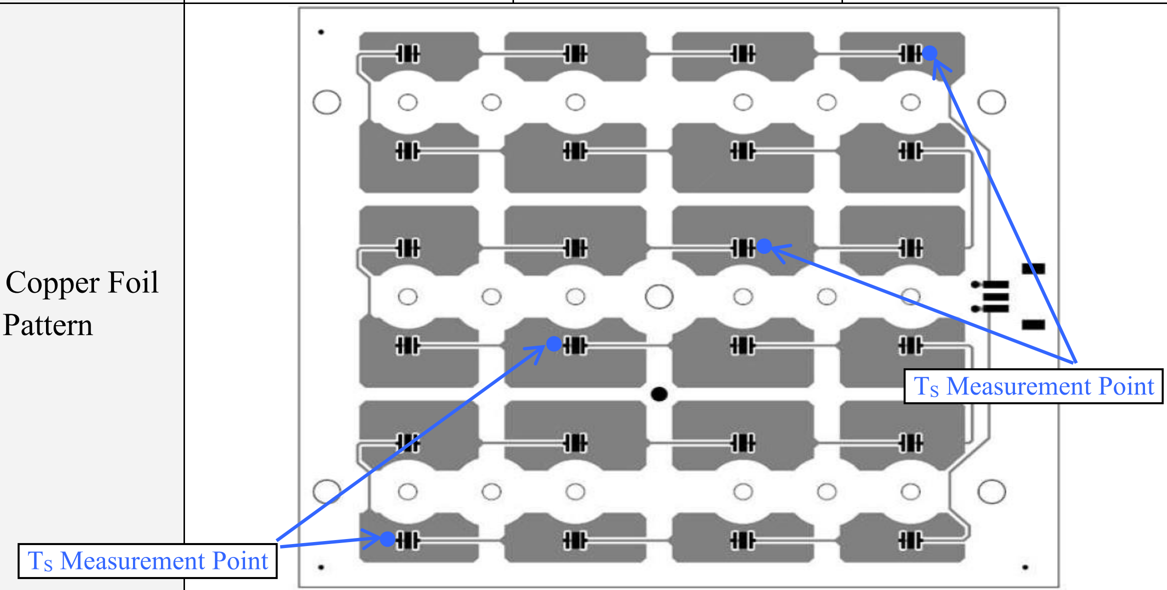
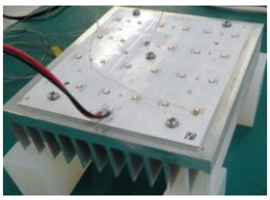
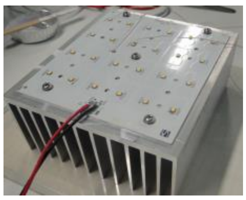
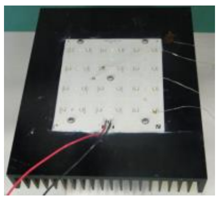
Part Number	NVSx219C		NVSx119C
Copper Layer Pattern	Pattern 1 	Pattern 2 	Pattern 3 
PCB Copper Foil Pattern			
Thermal Grease	Sunhayato Co., Ltd. SCH-301 Approximately 4.0 g (silicone resin)		
How to attach the PCBs to the heat sinks	M4 stainless screws with washers, Tightening torque: 50cN·m		
PCB Specifications	Material: Aluminum Dimensions: 119mm (L) x 136mm (W) x 1.6mm (T) Copper Layer Thickness: 35μm Insulation Layer's Thermal Conductivity: 2.7W/m·K		

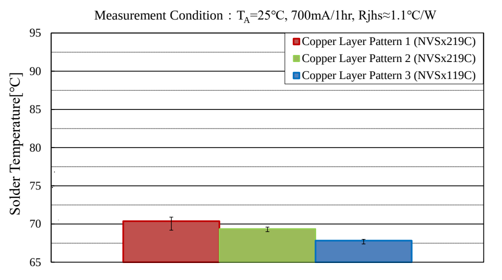
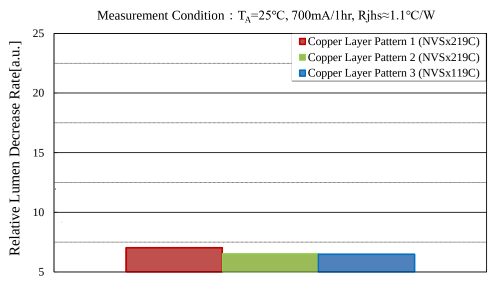
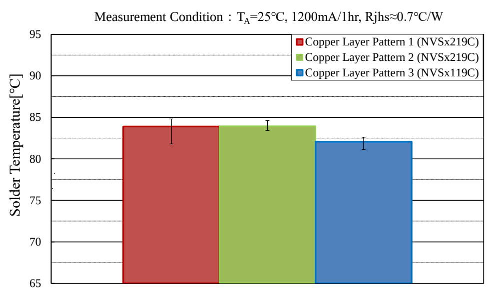
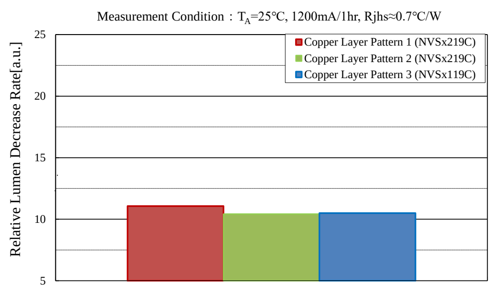
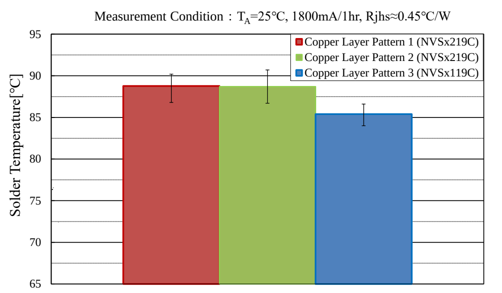
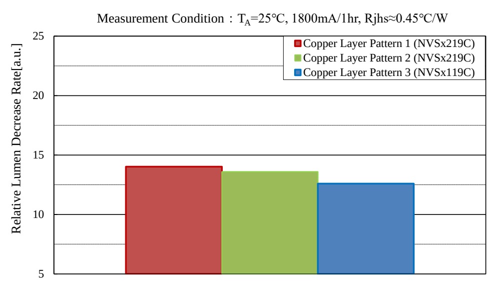
Table 2. Heat Sink Specifications and Operating Conditions

Heat Sink Thermal Resistance	Rjhs ≈ 1.1°C/W	Rjhs ≈ 0.7°C /W	Rjhs ≈ 0.45°C /W
Current Conditions	700mA	1200mA	1800mA
Heat Sink Dimensions	136mm(L) ×150mm(W) ×40mm(H)	133mm(L) ×150mm(W) ×64mm(H)	200mm(L) ×250mm(W) ×40mm(H)
Appearance			

3.1.2 Evaluation Results

The evaluation verified that when NVSx119C/NVSx219C LEDs were used in a module attached to a heat sink, the NVSx119C LEDs had a lower temperature at the TS measurement point and a smaller reduction in the luminous flux once the saturation temperature had been reached; this could lead to the conclusion that the NVSx119C LEDs have a better heat dissipation capability.
In comparison, of the two copper layer patterns used for the NVSx219C LEDs (i.e. Pattern 1 and Pattern 2), the LEDs soldered to Copper Layer Patten 2 showed better heat dissipation. Refer to Table 3 for more details on the evaluation results.

Table 3. Evaluation Results: Heat Dissipation Capability by Operating Conditions
(i.e. Copper Layer Patten, Current [I_F], Heat Sink Size)

<table>
<tr><th>Heat Sink</th><th>T_S Temperature
Temperature at the T_S measurement point once the saturation temperature has been reached Sample Size = Avg. T_S measurement points of 4 LEDs per PCB</th><th>Luminous Flux Reduction Rate
Measured from T_J ≈ 25°C (Initial) to T_J in saturation mode Sample size = 1 PCB</th></tr>
<tr><td>I_F=700mA
Rjhs ≈ 1.1°C/W
Size
136mm(L)
150mm(W)
40mm(H)</td><td>
</td><td>
</td></tr>
<tr><td>I_F=1200mA
Rjhs ≈ 0.7°C/W
Size
133mm(L)
150mm(W)
64mm(H)</td><td>
</td><td>
</td></tr>
<tr><td>I_F=1800mA
Rjhs ≈ 0.45°C/W
Size
200mm(L)
250mm(W)
40mm(H)</td><td>
</td><td>
</td></tr>
</table>

3.2 Heat Dissipation by Operating Current Value

3.2.1 Evaluation Method/Conditions

The evaluation in section 3.1.1 was designed to simulate actual operating conditions: if the heat sink is large enough, then it will be possible to use a large amount of current for the module. For this purpose, three different sizes of heat sinks were used and the current to the module was set according to the heat dissipation capability of the heat sink used with the module.

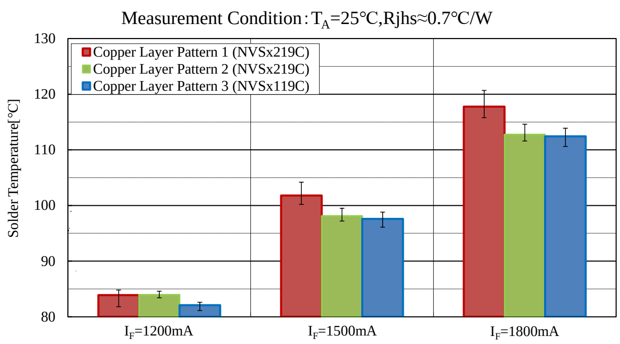
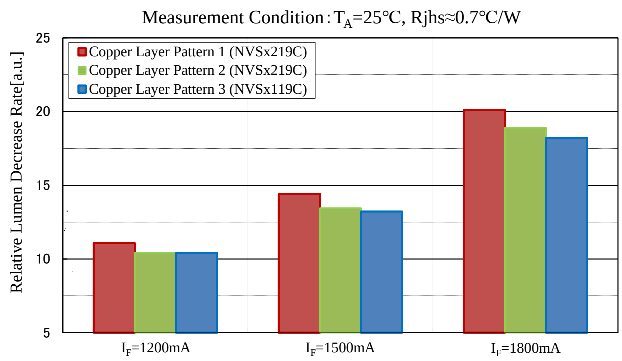
In this section, the application note evaluates the heat dissipation of NVSx219C and NVSx119C due to changes in the operating current when the module size is the same. The evaluation procedure is detailed as follows:

- The same three aluminum core PCBs were used as in the evaluation from section 3.1.1 (i.e. two copper layer patterns for NVSx219C LEDs and one copper layer pattern for NVSx119C LEDs) (See Table 1).
- Only one of the heat sinks used from the evaluation in section 3.1.1 was used: the heat sink with a thermal resistance Rjhs ≈ 0.7°C/W (See Table 2).
- Three predetermined input current values were used: I_F=1200mA, I_F=1500mA and I_F=1800mA.
- Four LEDs were chosen from the 24 LEDs per aluminum core PCB. Once the saturation temperature had been reached for those four LEDs, they were measured at the T_S measurement point (See Table 1).
- To evaluate the effect of the temperature saturation on the module's luminous flux (i.e. reduction in the luminous flux), measurements were performed immediately after the LEDs were turned on and once the saturation temperature at the T_S measurement point had been reached.

3.2.2 Evaluation Results

The evaluation verified that when NVSx119C/NVSx219C LEDs were used in a module attached to a heat sink, the NVSx119C LEDs had a lower temperature at the TS measurement point and a smaller reduction in the luminous flux once the saturation temperature had been reached; this leads to the conclusion that the NVSx119C LEDs could have a better heat dissipation capability.
In comparison, of the two copper layer patterns used for the NVSx219C LEDs (i.e. Pattern 1 and Pattern 2), the LEDs soldered to Copper Layer Patten 2 showed better heat dissipation. Refer to Table 4 for more details on the evaluation results.

Table 4. Evaluation Results: Heat Dissipation Capability by Operating Conditions (i.e. Copper Layer Patten and Current [I_F])

T_S Temperature Temperature at the T_S measurement point once the saturation temperature has been reached Sample Size = Avg. T_S measurement points of 4 LEDs per PCB	Luminous Flux Reduction Rate Measured from $T_J \approx 25°C$ (Initial) to T_J in saturation mode Sample size = 1 PCB
	

4. Summary

Under any of the evaluation conditions above, Nichia has verified that NVSx119C LEDs had better heat dissipation on average than NVSx219C LEDs. One of the possible reasons for these results is that the NVSx119C LEDs have electrodes that are larger in area than the NVSx219C LEDs allowing for better heat conduction from the LED to the PCB. Ensure that if NVSx219C LEDs are used for the chosen application, there are no issues with the copper layer design (i.e. poor heat dissipation).

In either case, it is important to ensure that the area of the copper layer is sufficiently large; however, since the NVSx119C LEDs have electrodes that are larger in area than the NVSx219C LEDs, even if the operating conditions/environment where the LED is operated do not allow the LED to sufficiently dissipate the heat, they will be able to offer better heat dissipation than the NVSx219C LEDs. Additionally, the NVSx119C LEDs have a simple design for the electrodes (i.e. only two electrodes: anode and cathode) that is an advantage over LEDs with anode/cathode electrodes and a die heat sink (e.g. easy to determine the copper layer pattern, size, position, etc.).

Note that the evaluation methods/conditions provided in this application note are examples and the data may vary depending on the LED model and/or the chosen operating conditions/environment; the contents of this document should be used for reference purposes only.

Light Emitting Diode

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