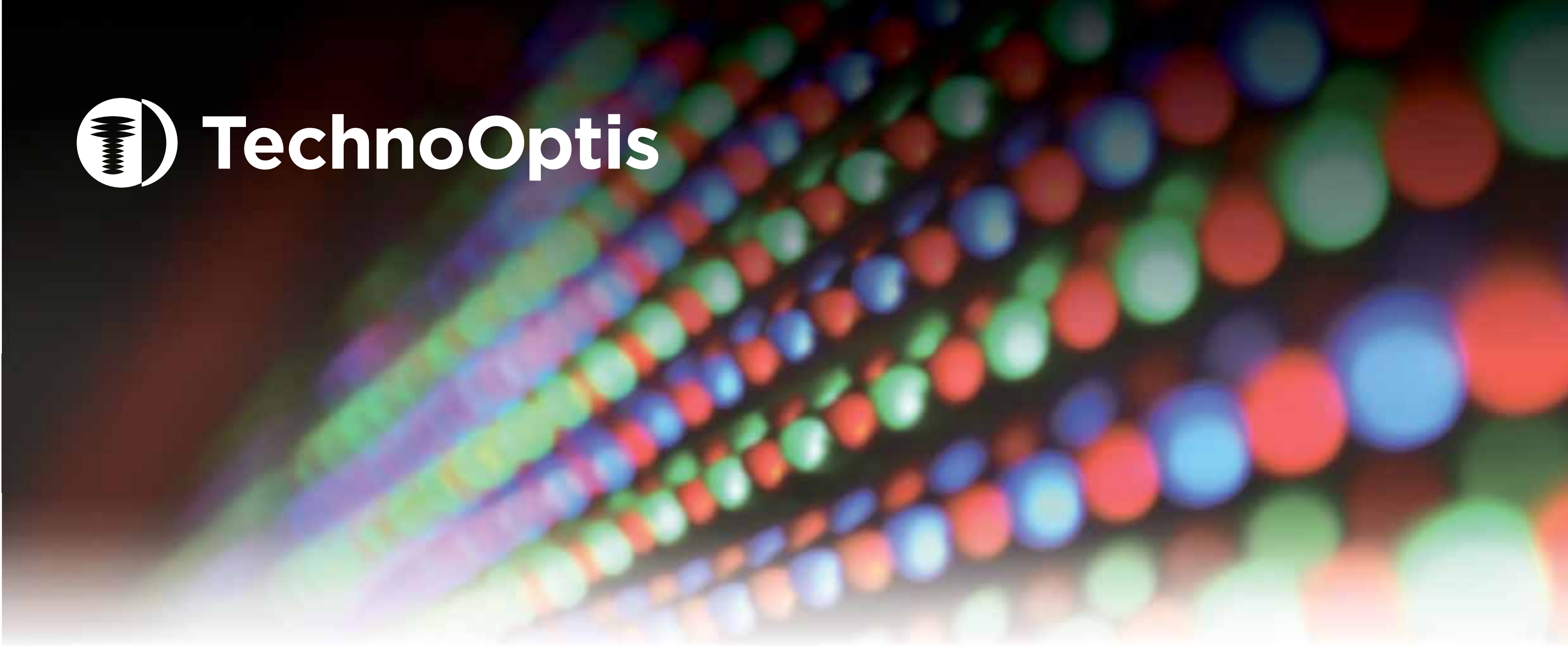


Example of optical measurement evaluation of Micro-LED

Evaluation and analysis example

① PL inspection (Die evaluation)
② EL inspection (Die evaluation)
③ Individual variation evaluation of subpixels in cell planes
④ Unevenness evaluation in cell planes
⑤ Measurement of leakage light by mixing color of color conversion method
⑥ Roughness evaluation in subpixel plane

Appendix / Glossary

TechnoOptis Co., Ltd.

Introduction

As a next generation display following LCDs (LCDs) and OLEDs (OLEDs), the development of micro-LEDs, quantum dot (QD) displays, etc. is becoming popular.
By miniating the chip size to less than 100 microns and nm levels compared to existing LEDs, many research institutes and companies are actively developing displays that have the performance of surpassing conventional LCDs and OLED displays. These devices are also ideal for new applications such as AR (augmented reality) / VR (virtual reality) / MR (mixed reality) / SR (alternative reality), automotive head-up displays (HUDs), micro projectors, and smartwatches, which are expected to expand the market in the future.

●Conventional LED chip measurement
In the past, LED chips used luminous flux (lm), luminous ity (cd), chromaticity, color temperature, peak wavelength, etc. as management units, and a method of combining integrated spheres and spectroradiometers has been commonly used for measurement (Fig.1).
However, since the micro LED has a very small chip, it is difficult to align it when installed in an integrated sphere.
In addition, devices equipped with micro LEDs are expected to have displays, etc., so they may be evaluated by luminance (cd/m^2) and chromaticity as well as panel evaluations such as LCDs and OLEDs.

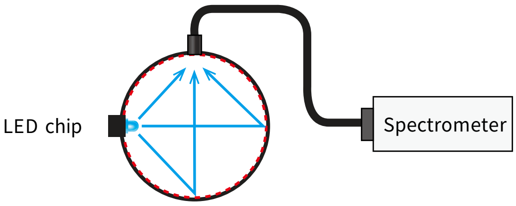


Fig.1 General LED measurements

●Flow of manufacturing of conventional micro LEDs (Fig.2)
Because micro LEDs are fine, it is very difficult to transfer LED die from wafers to substrates, and evaluation after incorporating them into cells increases repair costs such as cutting out and baking defective dies.
Photo luminescence (PL) and electro luminescence (EL) tests at the wafer level and die sorting can lead to improved yield and lower prices.
In addition, in cell evaluation after placing LED dies, it is necessary to evaluate optical characteristics directly related to product characteristics, such as individual variation of LED dies and uniformity of in-plane wavelength and emission intensity.
The following is the latest measurement examples for the development, design and mass production of micro LEDs.

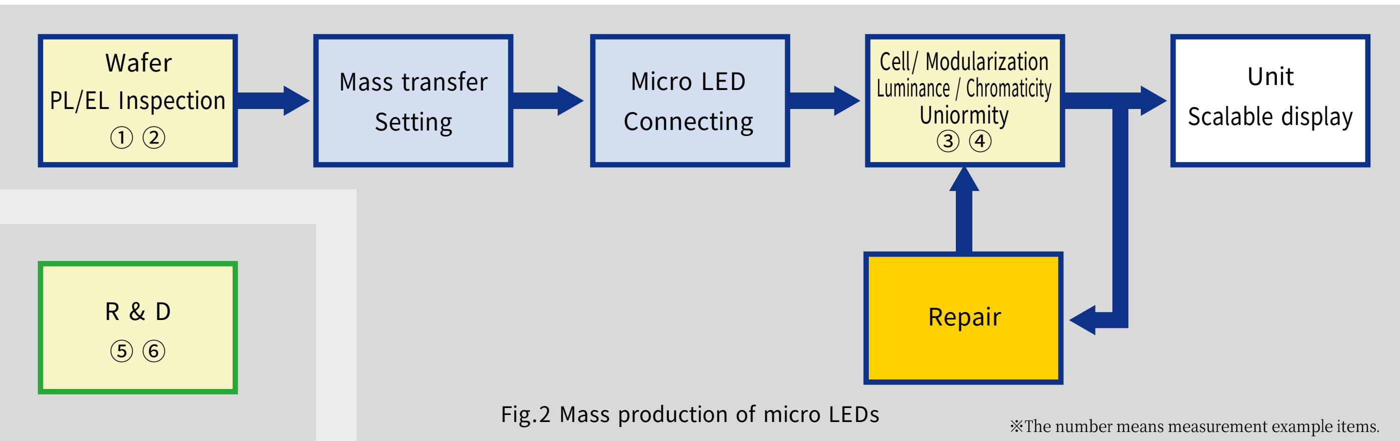


Fig.2 Mass production of micro LEDs

① PL Inspection (Die evaluation) Luminance

When UV light is irradiated on the wafer, the color conversion of the surface occurs. This property is used to determine the heterogeneity of in-plane materials by surface scratch inspection and detection of deposition unevenness.
Measure luminance using a high-resolution CCD camera and a two-dimensional luminance meter (Fig.3).

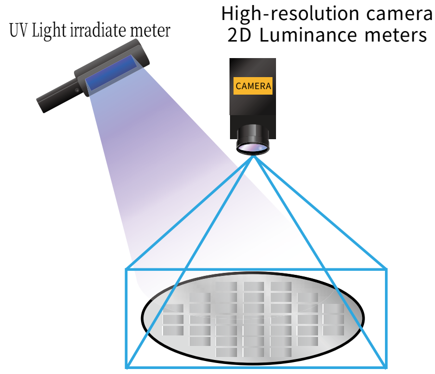


Fig.3 PL inspection

②EL Inspection（Die evaluation）

Dominant Wavelength | Peak Wavelength | Radiance

In general, when evaluating the die of micro LEDs, there is an evaluation method for measuring the spectral spectrum and peak wavelength by installing an integrating sphere on the light emitting surface and measuring it using a spectrometer via optical fiber (Fig.4).
However, because the die size is smaller, it is difficult to align, and it takes a very long time to evaluate because it is necessary to measure individually according to the emission point of each point.
For example, if more than 10,000 die on a 6-inch wafer is inspected, the 2D spectroradiometer SR-5100 series can be inspected in 1/12 of the time at 14 divide area than spot inspection using integral spheres (Fig.5).

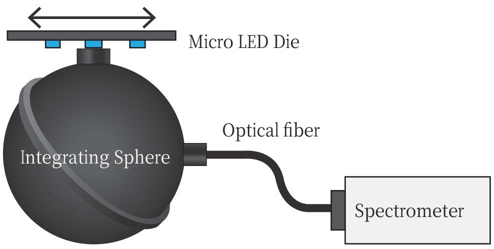
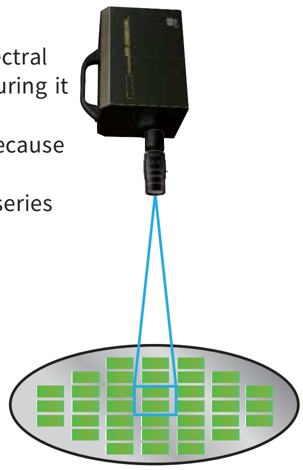


Fig.4 EL Inspection


Blue tape wafer
Fig.5 SR-5100 EL Inspection

③ Individual variation evaluation of subpixels in cell planes

Luminance | Chromaticity | Peak Wavelength | Angle chacteristics

In cells with micro LED dies mass transtransved and emitted modularized, optical measurement evaluation is often performed in the same way as display panels such as LCDs and OLEDs.
However, since the micro LED cell is even smaller than the conventional display, it was difficult to observe the entire screen at once in the measurement size of the macro type of the 2D spectroradiometer SR-5100, but by widening the angle of view using a zoom lens, etc., it is possible to check the emission status of the entire cell (Fig.6).
By performing a spectral inspection of sub-pixels from the automatic detection of emission points using the automatic spot function, it is possible to evaluate whether the performance of the sub-pixel brightness variation due to the individual difference of the LED affects the performance tothe micro LED display (Fig.7 to 9).
In addition, the angle characteristics emitted from ledfrom LED directivity may affect the unevenness of emission, and simultaneous inspection by a luminance meter installed at multiple angles can evaluate the viewing angle characteristics (Fig.10).

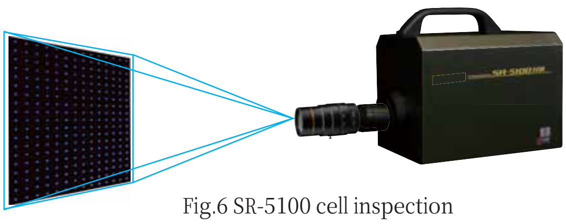


Fig.6 SR-5100 cell inspection

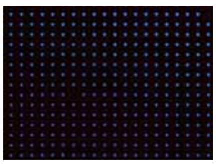


Fig.7 RGB color

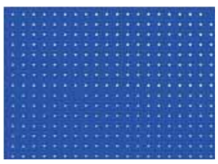


Fig.8 Pseudo color

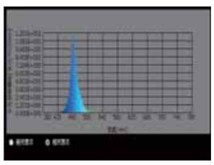


Fig.9 Spectram

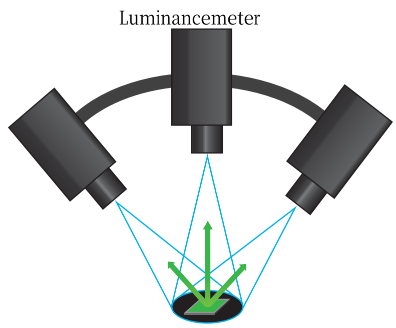


Fig.10 Angle characteristics

④ Unevenness evaluation in cell planes

Luminance | Chromaticity | Spectram | Peak Wavelength | Dominant Wavelength | Uniformity

When measuring the uniformity of the entire LED light-emitting cell, the conventional spot-measuring spectrometer required multi-point measurement.
Micro LEDs have a wider color gamut than typical LCDs and OLEDs, so they have a wider color gamut and are able to express images more realistically. As a result, the needs of measuring instruments are changing, and more accurate and high-performance instruments are required.
On the other hand, it is possible to measure uniformity (Fig.11) with a typical XYZ filter built-in, but it is not possible to accurately measure the absolute brightness and chromaticity values, and the error may increase, also it is not possible to find variations or problems with emission spectrum wavelengths, because it does not perform spectroscopic measurements.
By performing spectroscopic measurements on the entire surface using the 2D spectroradiometer SR-5100 series, in addition to being able to perform high accuracy evaluation of the heterogeneity of brightness and chromaticity in the surface, it is necessary to high-precision evaluation of spectral data, peak wavelength, dominant wavelength on the multiple points high-precision evaluation such as the dominant wavelength (Fig.12, 13).

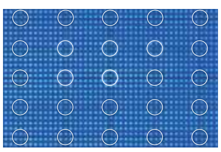


Fig.11 Uniformity

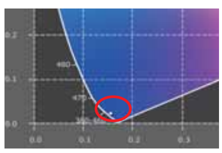


Fig.12 Chromaticity diagram

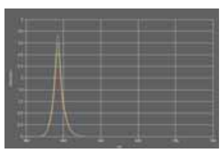


Fig.13 Spectram

⑤ Measurement of leakage light by mixing color of color conversion method

Luminance | Chromaticity | Spectram | Dominant Wavelength | Excitation purity

The color conversion method is a technology that displays RGB by changing the color that emits light by using QD and phosphor for micro-sized blue LEDs and UV-LEDs.
When QD is used for the blue LED, blue light leaks through the gap between the particles of qD (Fig.14), so the output of blue light may be generated when G or R is emitted (Fig.15).
This can cause color mixing and have a significant effect on the gamut (Fig.16). A 2D spectroradiometer SR-5100 series and microscopes are combined to measure for leakage light verification. It cannot be measured by XYZ type.
In addition, in order to verify and evaluate the mixed color, it may be evaluated in the subpixel of the die.
Using an objective lens of a 20-magnification microscope (Fig.17) can measure an area of 0.5 mm at 2248 x 2048 pixels (0.17 um/Pixel), allowing for variation evaluation of luminance, chromaticity, and spectrum within die subpixels.

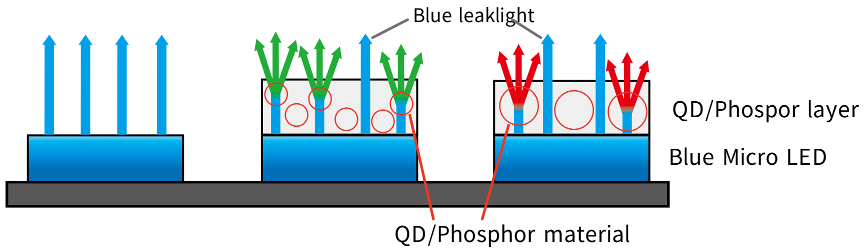


Fig.14 Blue leaklight

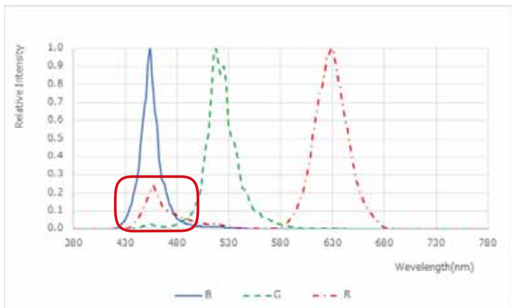


Fig.15 Spectral color mixing

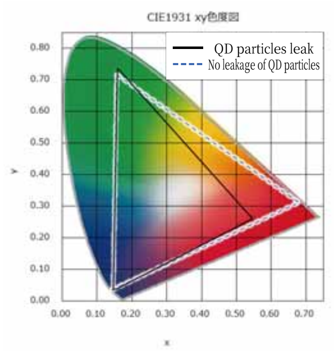


Fig.16 Color error due to color mixing

Fig.17 SR-5100 ＋ Metallugical microscope

⑥ Roughness evaluation in subpixel plane

Luminance | Chromaticity | Spectram | Dominant Wavelength | Excitation purity

If there is uneven deposition during wafer deposition during micro LED production, a roughness occurs in the pixel of the die (Fig.18).
The occurrence of this roughness affects the peak wavelength and luminance of the die, but the luminance of the micro LED die is very high, which can be difficult to visually confirm with a microscope. The use of a 2D spectroradiometer SR-5100 and a microscope improves the visibility of brightness uniformity in the plane (Fig.19).
In addition, it is possible to compare and evaluate luminance, chromaticity, spectral spectrum, etc. by specifying multiple points at once (Fig.20, 21).

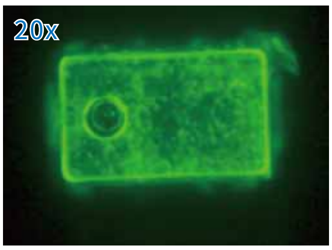


Fig.18 RGB cokor

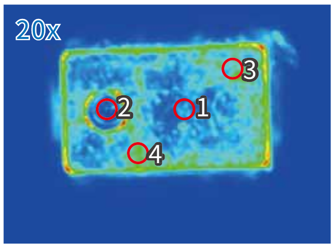


Fig.19 Pseudo color

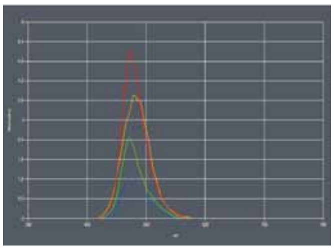


Fig.20 Spectram

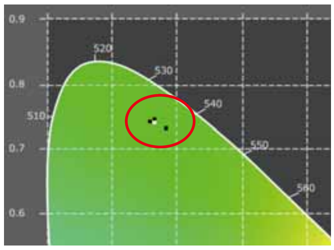


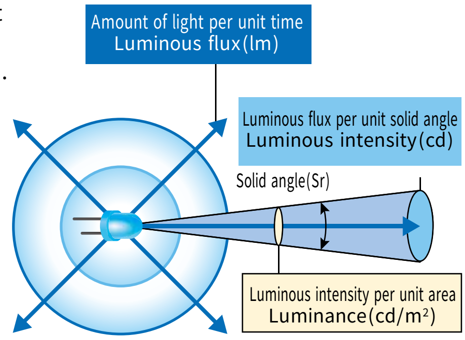
Fig.21 Chromaticity diagram

Appendix/Glossary

・Optical measurement unit

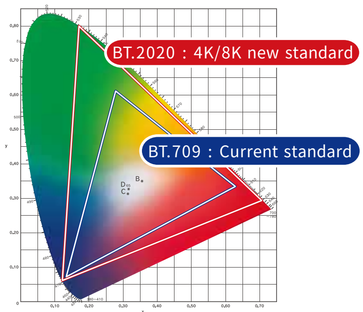
The radiant flux that outputs light per unit time in all directions as the radiation amount that light spreads as an electromagnetic wave, the radiant intensity that outputs light emitted per unit stereoscopic angle in a particular direction, and the radiant intensity that outputs per unit area are expressed as radiance.
Radiance can be calculated from the accrual of the emission spectrum (spectral radiance).
For physical radiation, the human eye is sensitive to brightness, and the amount of photometric value that takes into account its wavelength characteristics is the amount of photometric, each unit is called a luminous flux (lm), luminous intensity (cd), and luminance (cd/m2).

Radiant quantity	Unit	Photometry	Unit
Radiant flux	W	Luminous flux	lm
Radiant intensity	W/sr^1	Luminous intensity	cd
Radiance	$W/(sr^1 \cdot m^2)$	Luminance	cd/m^2



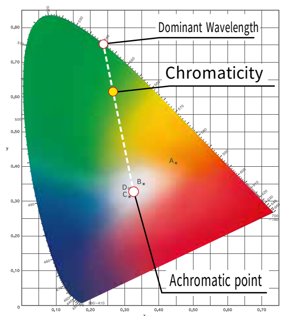
・New standards for chromaticity:BT-2020

There are various gamut standards that reflect the use of the color gamut, with the range within the chromaticity that can be displayed on the display as the gamut. Recently, in 2012, the image format Rec.ITU-R BT-2020 was published for ultra-high definition television (8K), which has a very high gamut standard. Because the triangle with RGB as the vertex on the chromaticity diagram spreads outward due to the expansion of the gamut, the spectral is generally narrow to the spectral to increase the chroma, so the instrument also requires high chromaticity accuracy.



・Dominant wavelength

Represents the wavelength equivalent to the color when a person's eye saw.
It is a numerical value obtained using the xy chromaticity value of the light source, and conceptually it is the image of the wavelength (single wavelength) in which the color of the light source is most affected.
In a chromaticity diagram, the wavelength corresponding to the intersection of the achromatic point and the spectral trajectory on the extension line of chromaticity coordinates, and the chromaticity error directly affects the main wavelength accuracy.

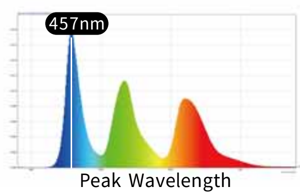


・Excitation purity

A number that represents the saturation of the color of the light source.
Indicates the ratio between achromatic points and chromaticity, chromaticity and dominant wavelength points, with1 (100%) at the maximum value.
If the chromaticity is close to achromatic (reference white point), the purity is low, and the closer it is to the dominant wavelength point (the colorless extension portion), the higher the purity.

・Peak wavelength

Unlike the dominant wavelength, the output of the spectral represents the highest wavelength. One of the factors is that the chromaticity error is due to the occurrence of emission wavelength shift of the light source. It is useful to check the peak wavelength to ensure that the emission spectral is output normally, because it may directly affect uniformity and gradation display.



Peak Wavelength

2D Spectroradiometer **SR-5100** Lineup

Standard lens ＋ Wide lens

SR-5100HWS

Telephoto lens

SR-5100HT

Macro lens

SR-5100HM

TechnoOptis

https://www.techno-optis.com/en

TechnoOptis Co., Ltd.

Formerly Topcon Technohouse Corporation

75-1 Hasunuma-cho, Itabashi-ku, Tokyo 174-8580 JAPAN
Phone : +81-3-3558-2666 Fax : +81-3-3558-4661
E-mail : techno-info@topcon.co.jp URL : https://www.techno-optis/en

techno optis

Printed in Japan 2025 04 E4