TechnoOptis

Next-generation displays (OLED/Mini-LED/Micro-LED) Evaluation and analysis for quality defects

Evaluation and analysis example

1. Gradient Mura
2. Individual differences of subpixel
3. Mura in subpixel
4. Color mixture (light leaking from bank material)
5. Residual image(Burn-in)
6. High precision and speed measurement in production line
7. Organic EL display standard

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Introduction

The organic EL displays are growing as a next-generation displays, but also Micro LED display, Quantum dot display have been developed actively. Existing LED that wavelength is from 300 to 350 µm level have already spread to the market as digital signage displays.
By miniaturizing LED chips to 100 - 200 µm level (Mini LED), under 100µm level or nm level, the displays with performance superior to LCD and OLED displays are also active developed by many research institutes and companies. These are also said most suitable devices for new application to project the image into the air such as a head-up display(HUD) for vehicle, a micro projector, AR (Augmented Reality), VR (Virtual Reality) and MR (Mixed Reality), and will grow into a large market in the future.
The following is an example of defects analysis for OLED, Mini LED, Micro LED, and so on when development and design of miniaturized displays for next-generation, and mass production.

1.Gradient Mura OLED Mini-LED Micro-LED

Gradation means the extent of variation from most brightness to most darkness of pixel, and shown 256 gradation (0 to 255) of each color. A vertical line is luminance and a horizontal line is gradation. It is sometimes called a gamma characteristic or gray scale. (Fig.1)
The gray level in the gradation evaluation affects the overall color display of the display at the gray level and subpixel level when there is a difference in the RGB organic material for the subpixel in the OLED display.
In the case of measuring the cross section of luminance on the display (Fig.3), in the high gradation in-plane can be seen uniformly, but in the low gradation, as shown in the lower figure (Fig.4) locally inhomogeneity. Even with data measured with a general 2D luminance meter (XYZ filter method), although it is found the unevenness, detailed analysis cannot be performed.
As the 2D spectroradiometer SR - 5100 (Fig. 2) can measure a spectroscopically on whole pixels, confirming the spectral data of the site of occurrence of gradation unevenness can solve the problem of irregularities It is possible to wash out (Fig.5, 6).

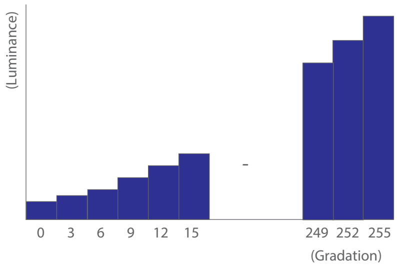

Fig.1 Gradation characteristic

Fig. 2 Evaluation image of SR-5100

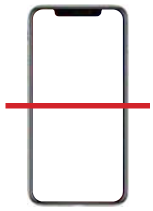
Fig.3 Measurement cross-section point

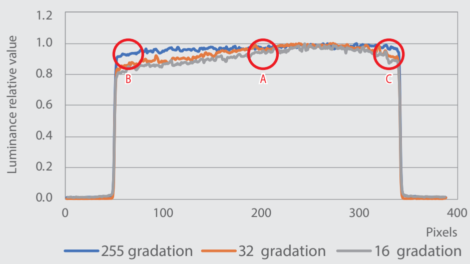

Fig.4 Gradient Mura

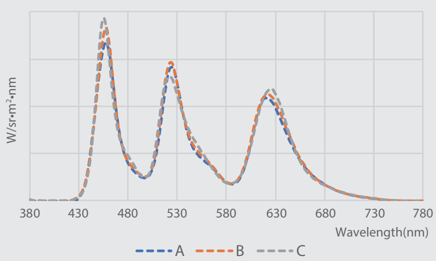

Fig.5 255 gradation

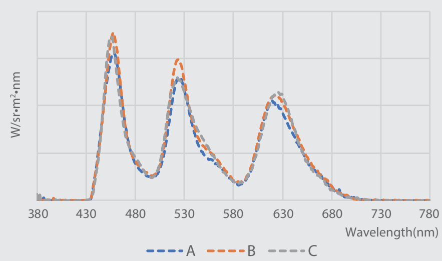

Fig.6 32 gradation

2. Individual differences of subpixel OLED Mini-LED Micro-LED

The pixels of the OLED display are composed of RGB subpixel, the output of each subpixel is individually controlled and the brightness (luminance) and color of the pixels are determined by the combination of the outputs of the subpixel.
Even if the same electrical signal is input to the same color subpixel due to manufacturing variations, the luminance may vary, as a result luminance vary between both of pixels(Fig.9-11).
Luminance variation at the subpixel level has a big influence on performance. These are also the same for Mini-LED and Micro-LED display, and the individual quality of the subpixel will affect the display quality.
In the data measured with a general 2D luminance meter (XYZ filter method), it is possible to find the difference of the luminance and chromaticity, but in fact it is not to be able to grasp what is the problem unless confirmation by spectroscopy spectrum.
Evaluation can be done by attaching a 2D spectroradiometer SR - 5100HM to a metallurgical microscope with a high magnification objective lens(Fig. 7). The cause of individual difference can be clarified by spectroscopically measuring subpixels.


Fig. 7 SR-5100 + Metallurgical microscope

•Spectral comparison of OLED each subpixels

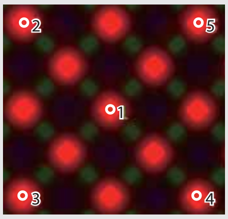

Fig.8 OLED subpixels
Red emitting

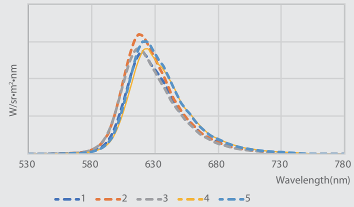

Fig.9 Red

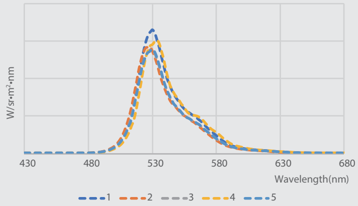

Fig.10 Green

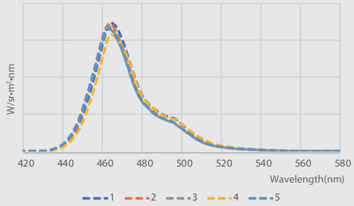

Fig.11 Blue

•Spectral comparison of Micro-LED each subpixels

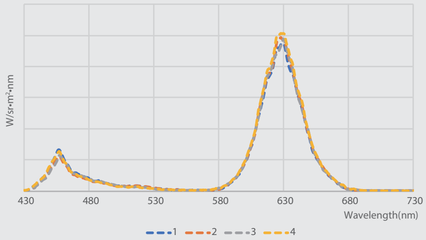

Fig.12 Red

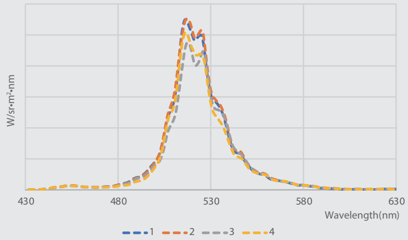

Fig.13 Green

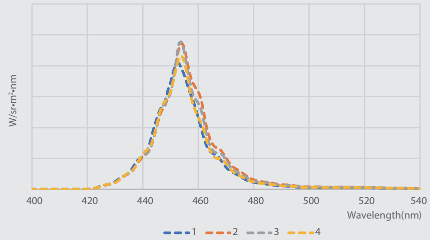

Fig.14 Blue

3. Mura in subpixel OLED Mini-LED Micro-LED

Along with the miniaturization of subpixels, the demand for pixel level measurement is increasing. Looking at Fig.16, it turns out there is a difference in spectroscopy of the OLED pixel. This is caused by the difference in film thickness and film quality distribution, and film thickness and film quality are caused by evaporation or metal mask misalignment.

In order to satisfy the requirement for evaluation of sub-pixel in-plane irregularity, it can be evaluated using Fig.7. By using a microscope objective lens of 20 times, the microscope it is possible to measure an area of 5 mm at 2448 × 2048 pixels (0.17 µm / Pixel). Also, to evaluation for further miniaturized subpixel, it can measure in detail by raising the magnification of the metallic microscope. Likewise, it is also possible to evaluate the subpixel in-plane emission irregularities of Mini LED and Micro LED. (Figs. 19 to 21)

•Spectral comparison in OLED subpixel

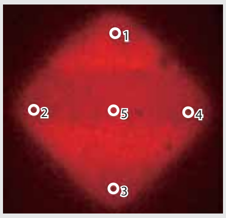

Fig. 15 OLED subpixels
Red emitting

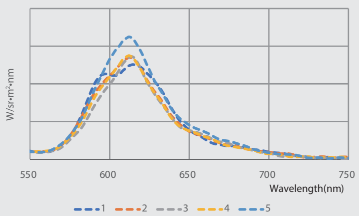

Fig.16 Red

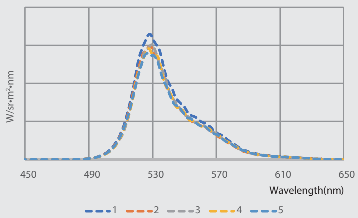

Fig.17 Green

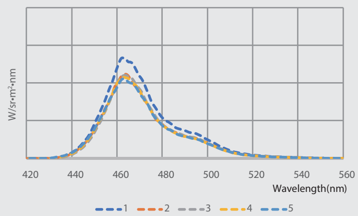

Fig.18 Blue

•Spectral comparison in Micro LED subpixel

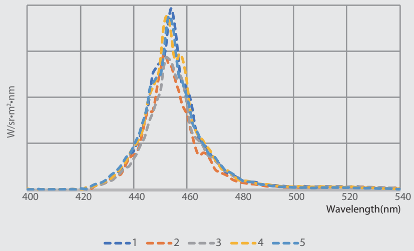

Fig.19 Red

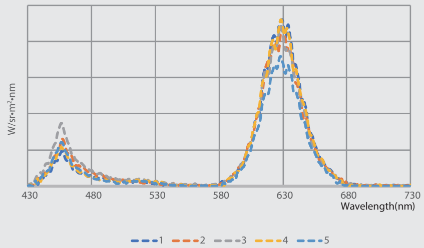

Fig.20 Green

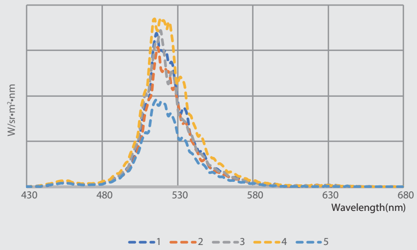

Fig.21 Blue

4. Color mixture (light leaking from bank OLED

The general bank material of OLED is currently a transparent type for reducing outgas, and leaking light and reflection due to light passing through a bank defect or a bank are occurring(Fig.22). For example, when only red (R) is displayed, light leaks to neighboring subpixel and green (G) and blue (B) also will emit light. Fig. 23 shows the luminance (pseudo color) with a general 2D luminance meter (XYZ filter method) when only the emission of red (R), but it can only distinguish red (R) emission.

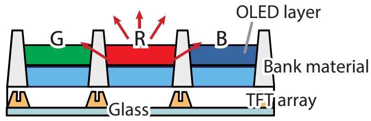

Fig.22 OLED constructional example

As shown in Fig. 24 to 26, it is possible to display images for each measurement wavelength by spectroscopic measurement using Fig.7, so that it is possible to display intensity images for each wavelength and obtain the spectral distribution of subpixel, and it is possible to evaluate how is color mixing.

Green (G) and blue (B) is affected when emitting red (R) light, red (R) and blue (B) is affected when green (G) light is emitted, It also can obtain the data to grasp that only red (R) is affected when blue (B) light is emitted.

OLED Red

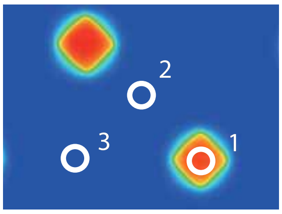

Fig.23 Pseudo color

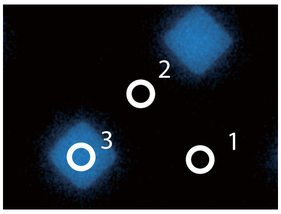

Fig.24 466nm

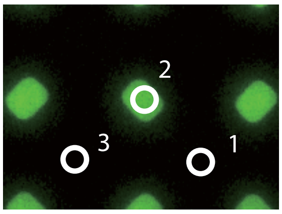

Fig.25 531nm

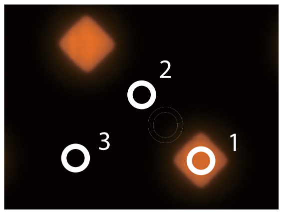

Fig.26 620nm

•Spectral data in OLED subpixel

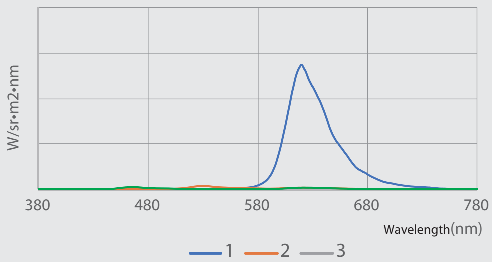

Fig.27 Spectral distribution of leaking light

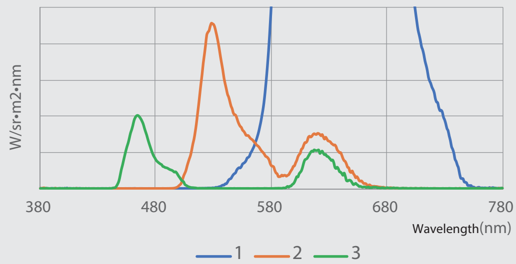

Fig.28 Spectral distribution of leaking light (Enlarged graph)

OLED Green

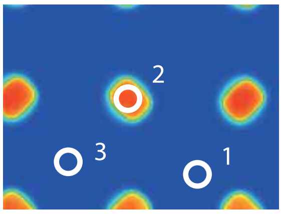

Fig.29 Pseudo color

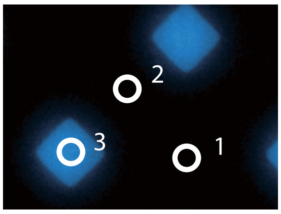

Fig.30 466nm

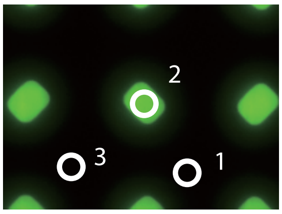

Fig.31 531nm

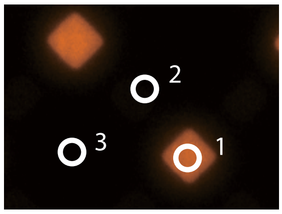

Fig.32 620nm

OLED Blue

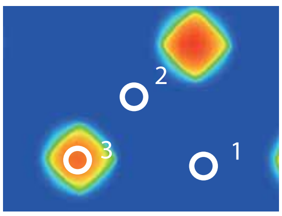

Fig.33 Pseudo color

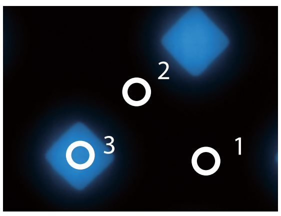

Fig.34 466nm

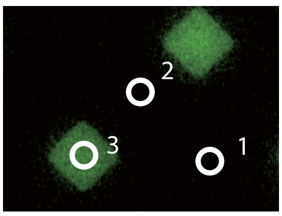

Fig.35 531nm

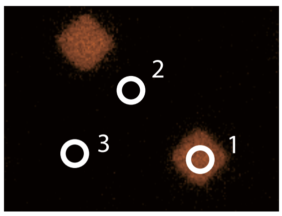

Fig.36 620nm

5. Residual image(Burn-in) OLED

When the OLED display has been lit for a given length of time, even if switching to the next screen, the previous image will remain in a slightly displayed state.
After displaying gray on a screen, black and white image is displayed for 10 seconds, and when it is evaluated how long the residual image existed after returning to gray again on the screen, it took about 2 minutes to return to the original gray image(Fig.40, 41).
In order to evaluate the fluctuation of the residual image by sampling inspection of quality control etc., it is necessary to have a measuring instrument that can be measured at high speed, and if it is UA-20 (Fig. 39), it is possible to measure temporal change of data by interval of approx. 1.7 seconds. Also, as it is small size, evaluation is possible without taking up the installation space.

Fig.39 Measurement image

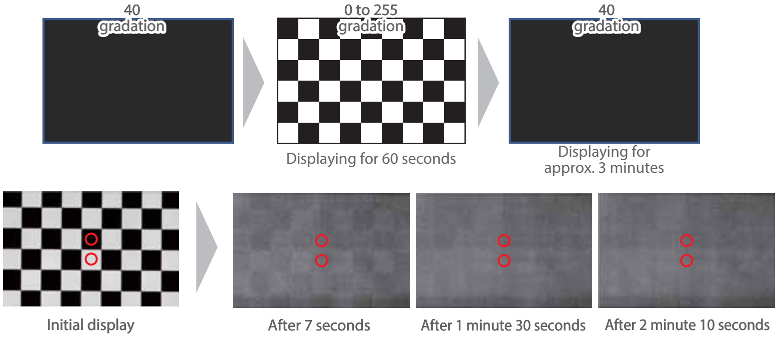

Fig.40 Result for residual image measurement

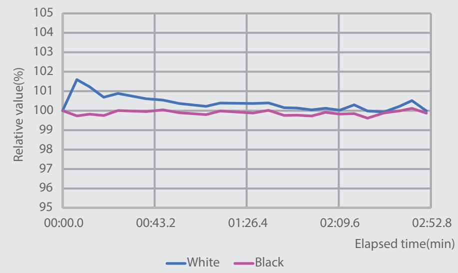

Fig.41 Luminance change

6. High precision and speed measurement in production line OLED Mini-LED Micro-LED

In production line for the next generation display such as OLED, there is a demand to measure highly accurate evaluation with high speed.Basically, there are evaluations of red (R), green (G), blue (B), white (W), and gray, and in the case of low gradation, as the measuring instrument needs to gain the light intensity, the integration time will take long time and measurement time will be long.In the spot type spectroradiometer SR- 5series (Fig.42) equipped with high speed mode that is a modified measurement algorithm, the measurement precision is almost same when measuring the 4 gradations of the display(Fig.48) using the HIGH SPEED mode, and measuring time is shorten from 129 (Approx. 2 minutes) to 39 seconds. so that it is possible to respond to production lines with high precision and high speed measurement by spectroscopy. For other gradation examples, refer to Figs. 43 to 46.

Fig.42 Spectroradiometer SR-5A

•Measuring time of each gradation

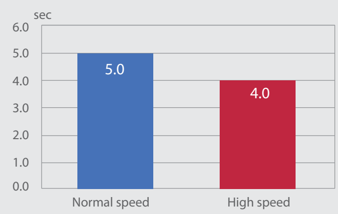

Fig.43 255 gradation (607cd/m²)

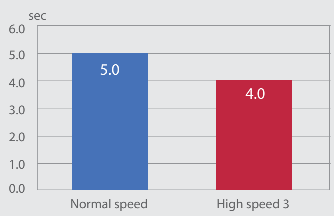

Fig.44 24 gradation (3.5 cd/m²)

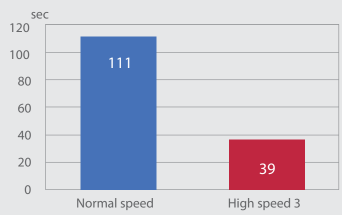

Fig.45 4 gradation (0.077cd/m²)

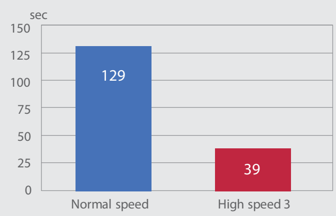

Fig.46 0 gradation (0.0002cd/m²)

SR-5A measurement condition : Auto mode

7. Organic EL display standard OLED

The evaluation method of the Organic EL Display module is standardized by JEITA (Japan Electronics and Information Technology Industries Association).
1. ED-2810 Measuring methods for Organic EL Display modules.
2. ED-2811A Measuring methods for Organic LED Display modules(II) -Image sticking, Lifetime-

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