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Nanotechnology - Nano-enabled Optoelectrical Display - Measurement of Optical Performance for Quantum Dot Enabled Light Conversion Film

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量子点光转换膜光学性能测试方法

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1 Scope

This document describes the test method for the optical performance of quantum dot light conversion films, including method principles, instruments and equipment, test samples, test procedures, data processing and test report, etc.

This document is applicable to the measurement of the optical performance of quantum dot light conversion films for liquid crystal display devices. The measurement of the optical performance of other types of light conversion films may take this as a reference.

2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 2410-2008 Determination of the Luminous Transmittance and Haze of Transparent Plastics

GB 19510.1-2009 Lamp Controlgear - Part 1: General and Safety Requirements

GB/T 20147 CIE Standard Colorimetric Observers

GB/T 37664.1-2019 Nanomanufacturing - Key Control Characteristics - Luminescent Nanomaterials - Part 1: Quantum Efficiency

3 Terms and Definitions

The terms and definitions defined in GB/T 37664.1-2019, and the following are applicable to this document.

3.1 quantum dot

Nanoparticles that exhibit size-dependent properties due to the quantum confinement effect of electronic states.

[source: GB/T 32269-2015, 4.7]

3.2 quantum dot light conversion film; Q-LCF

An optical film that converts high-energy photons of a specific wavelength into low-energy photons of another or several wavelengths through quantum dots.

3.3 peak wavelength

The wavelength corresponding to the maximum peak intensity in the spectrum.

NOTE: the fluorescence emission spectrum of quantum dot light conversion films usually has multiple emission peaks, and each emission peak corresponds to the peak wavelength of a quantum dot.

3.4 quantum yield

The photon emission efficiency of luminescent materials.

NOTE: it is the ratio of the number of emitted photons to the number of absorbed photons.

[source: GB/T 36081-2018, 3.2, modified]

3.5 haze

The ratio of the scattered luminous flux that deviates from the direction of the incident light and passes through the specimen to the transmitted luminous flux.

NOTE 1: it is expressed in percentage.

NOTE 2: in this document, only scattered luminous flux that deviates from the direction of incident light by more than 2.5° is used to calculate haze.

[source: GB/T 2410-2008, 3.1, modified]

3.6 luminous transmittance

The ratio of the luminous flux passing through the specimen to the luminous flux irradiating the specimen.

NOTE: it is expressed in percentage.

[source: GB/T 2410-2008, 3.2, modified]

3.7 luminance uniformity

The ratio of the minimum luminance to the maximum luminance in the test area of the quantum dot light conversion film.

3.8 color non-uniformity

The maximum chromaticity deviation value between the center and non-center of the test area

of the quantum dot light conversion film.

3.9 light conversion efficiency; LCE

The ratio of the number of fluorescent photons emitted by the quantum dot light conversion film to the number of absorbed photons of the backlight.

3.10 photon absorptance; PA

The ratio of the number of backlight photons absorbed by the quantum dot light conversion film to the number of backlight photons.

3.11 full width at half maximum; FWHM

The peak width at half the light intensity of the peak wavelength.

4 Symbols

The following symbols are applicable to this document.

H: haze

L: luminance

L_u: luminance uniformity

L_{min}: minimum luminance

L_{max}: maximum luminance

T: transmittance

W_F: full width at half maximum

λ_p: peak wavelength

(x, y): CIE 1931 standard colorimetric system, chromaticity coordinates

5 Method Principles

Based on the background test platform, perform quantitative measurement on the optical performance of the quantum dot light conversion film. The key parameters of the optical performance of the quantum dot light conversion film mainly include luminance and luminance uniformity, chromaticity and color non-uniformity, light conversion efficiency and photon absorptance, luminous transmittance and haze. Luminance uniformity and color non-uniformity reflect the consistency of the sample preparation process and are measured using the non-section method. Luminance and chromaticity characterize the optical parameters of the

controls the heat emitted by the backlight system to the sample stage, so that the temperature of the sample stage is not higher than 50 °C.

The backlight shall adopt a light-emitting diode (LED) light source consistent with the display equipment using the quantum dot light conversion film. A light source with a peak wavelength of 447.5 nm ± 2.5 nm and a full width at half maximum not greater than 20 nm should be used.

7 Test Sample

The test sample of the quantum dot light conversion film shall be selected with no curling, cracking, breakage, wrinkles, surface scratches or dirt on the cut surface. Cut it into a size that completely covers the background test area and shall be no less than 18 cm × 18 cm. The test sample is randomly cut from one or multiple quantum dot light conversion film samples of the same model, with no less than 3 parallel samples.

8 Test Procedures

8.1 Backlight System Debugging

Before testing the optical performance of the quantum dot light conversion film, the backlight system of the test platform needs to be debugged. The debugging method is as follows.

a) Confirm that the test platform is in an unloaded state.

b) Turn on the power switch of the backlight system and confirm that the platform is in normal working condition.

c) Use a spectral radiometer to measure the radiant illumination or luminance value at the center of the upper surface of the sample stage, and adjust the output power of the power supply, so that the radiant illumination on the surface of the sample satisfies the value agreed upon with the user.

d) Pre-heat the backlight system, and the pre-heating time is not less than 30 minutes. After pre-heating, repeat step c).

e) Continuously monitor the luminance and chromaticity changes of the backlight. It is required that the luminance change within 5 minutes is not greater than 2%, and the difference between the maximum and minimum chromaticity coordinates is not greater than 0.001.

f) During the debugging process, the temperature of the test platform does not exceed 50 °C.

8.2 No-load Test

In order to measure the fluorescence emission spectrum, luminance and chromaticity values of

7---spectral radiometer.

Figure A.1 -- Integrating Sphere Spectral Radiometer

The light source is an LED with a peak wavelength of 447.5 nm ± 2.5 nm. The radiant illumination incident from the light source to the sample surface is not less than 4 mW/cm^2, with reference to 6.5.

The light source auxiliary part shall use an inverted cone-shaped reflection cup with a surface reflectivity of not less than 90%, so that the light source emits light in a directed manner without light leakage. There is a platform in the vertical direction directly above the light source auxiliary part for the horizontal placement of sample.

The transparent sheet keeps the sample flat and close to the light source, so as to avoid backlight leakage.

The block screen and light outlet are built-in components of the integrating sphere. The block screen is used to block direct light from the quantum dot light conversion film that directly enters the detector without diffuse reflection.

A.2.2 Integrating sphere

The specifications of the integrating sphere:

---The diameter ϕ is greater than 3 times the maximum size of the test sample;

---Good spatial uniformity;

---Reflectivity greater than 90%;

---Equipped with 4π measurement mode.

A.2.3 Spectral radiometer

The spectral radiometer measures the spectral radiation power, and the equipment performance complies with the requirements of 6.3.

A.3 Test Method

A.3.1 Test sample

The test sample is prepared in accordance with the requirements of Chapter 7, and the sample size covers the light source range of the integrating sphere.

A.3.2 Test procedures

A.3.2.1 Light source debugging

Before the test, the light source needs to be debugged. The light source debugging process is as

follows:

a) Make sure the test platform is in an unloaded state;

b) Turn on the power switch of the light source system and confirm that the platform is normally operating;

c) Pre-heat the backlight system, and the pre-heating time is no less than 30 minutes. After pre-heating, continuously monitor the change in luminous flux of the light source, and the change in luminous flux is required to be no more than 1% within 5 minutes;

d) During the debugging process, the ambient temperature shall comply with the content of 6.1.

A.3.2.2 Sample test

The sample testing procedures are as follows:

a) Complete the light source debugging, place a transparent sheet on the light source, and test the radiated power spectrum $S_0(\lambda)$ in the unloaded state;

b) Remove the transparent sheet, place the sample and use the transparent sheet to cover it, and test the radiated power spectrum $S_1(\lambda)$ of the sample;

c) Repeat step b), and successively test the radiated power spectrum of all samples.

A.4 Data Processing

The calculation method for the quantum yield and absorptance is described below.

a) The spectral radiation power $S_1(\lambda)$ in the unloaded state and spectral radiation power $S_2(\lambda)$ of the sample. Read the peak wavelength λ_p of each peak in the $S_2(\lambda)$ spectrum and the full width at half maximum W_F corresponding to each peak wavelength.

b) Record the wavelength at the lowest luminance point between the first emission peak (light source) and the second emission peak (fluorescence), starting from the low wavelength side of the spectrum, as x nm. Record the band 380 nm ~ x nm as the backlight excitation band and record the band x nm ~ 780 nm as the fluorescence emission band.

c) In accordance with Formula (5), respectively calculate the number of photons n_1 in the range of 380 nm ~ x nm of the spectrum $S_1(\lambda)$ and the number of photons n_2 in the range of x nm ~ 780 nm; calculate the number of photons n_3 in the range of 380 nm ~ x nm of the spectrum $S_2(\lambda)$ and the number of photons n_4 in the range of x nm ~ 780 nm.

d) Respectively calculate the quantum yield QY and the absorptance ABs in accordance

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