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TECHNICAL SPECIFICATION

Nanomanufacturing - Product specification -
Part 4-3: Nanophotonic products - Blank detail specification: quantum dot enabled light emitting diodes

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Nanomanufacturing - Product specification - Part 4-3: Nanophotonic products - Blank detail specification: quantum dot enabled light emitting diodes

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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

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A list of all parts in the IEC 62565 series, published under the general title *Nanomanufacturing - Product specification*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

This document details how to specify the key control characteristics of quantum dot enabled light emitting diodes (QLEDs) in a systematic and consistent manner. It gives the key control characteristics (KCCs) and corresponding measurement methods related to QD materials, QD inks, QD films and QLED prototype devices.

Typically, the applications of QDs in displays have two technological pathways: photoluminescence (PL) and electroluminescence (EL). The former is passive luminescence, where green and red light is generated by excitation via higher energy blue light illumination. The latter is active luminescence. In electroluminescent QLEDs, electrons and holes are injected into the colloidal QD emissive layer to form excitons that then radiatively decay to release photons. Electroluminescent QD display technology has become more and more appealing in research and industry recently due to its high contrast, fast response, foldability, and ultra-thin structure, as compared with the use of photoluminescent QDs.

The importance of QDs to QLED performance cannot be overemphasized. Specifically, its chemical composition, core-shell structure, crystallinity, energy levels for both conduction and valence bands, static optical properties, ultrafast optical properties and so on have been demonstrated repeatedly in numerous publications to play major roles in affecting device internal quantum efficiency (IQE), external quantum efficiency (EQE) and stability. Slight QD material modifications lead to noticeable changes in the device performance. Although multiple characterizations for each of these factors have been reported in different publications, thus far there are no unanimous protocols established. Therefore, it is important to report a systematic and well-accepted protocol of characteristics.

Preparation of QD inks suitable for the ink-jet printing techniques is crucial for the mass production of QLED-based displays. This is a non-trivial assignment since the quality of ink-jet printed films is closely related to the properties of the inks. On one hand, it is important to preserve the solubility and optical stability of QDs; and on the other hand, the inks' compatibility with substrate and process conditions is crucial to produce excellent films. Decent progress has been made, but there is still more to be done to achieve reproducible high-quality films. Standardization of the detailed physical properties will definitely facilitate this process.

Film qualities for QDs as well as other functional layers – including electron transfer, hole transfer, and hole injection layers – are directly related to the balance of carrier injections, which is highly correlated to the device performance. Thus, it is extremely important to develop the ability to reproducibly prepare uniform film. Characterizations of film thickness, uniformity, QD optical stability, physical stability and conductivity are necessary to assure the quality of prepared films.

The luminance of QLEDs is one of the most important parameters, determining the accuracy of device lifetime conversion. Unfortunately, despite its significance, the reported results from different laboratories and institutes contradict each other. Currently, there are three widely used methods for this measurement. They are spectroradiometer, silicon photodetector and integrating sphere. It turns out the major discrepancies arise from the different methods used. Particularly for prototype QLEDs, different luminance measurement methods lead to rather different results. Therefore, the standardization of luminance measurement for QLEDs is urgent in order to obtain reliable results. And this is the cornerstone for the further improvement of QLED research.

This document also provides information about measurement methods and existing standards concerning the correct determination of key control characteristics.

1 Scope

This part of IEC 62565 establishes a blank detail specification (BDS) for quantum dot enabled light emitting diodes (QLEDs) used for printed light emitting diodes (LEDs).

This document is intended to be used for display applications.

The relevant key control characteristics (KCCs) include optical, physical, chemical, and structural properties of colloidal quantum dots (QDs). For each KCC listed, methods and existing standards for their measurement are reported. The applicability of such methods and standards to different material categories (physical forms) of QDs, for example colloidal solution, inks, films, is indicated.

Numeric values for the KCCs are left blank as they will be specified between customer and supplier in the detail specification (DS). In the DS, KCCs can be added or removed if agreed between customer and supplier.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61010-2-033:2023, *Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 2-033: Particular requirements for hand-held multimeters and other meters for domestic and professional use, capable of measuring mains voltage*

IEC TS 62565-4-2:2018, *Nanomanufacturing - Material specifications - Part 4-2: Luminescent nanomaterials - Detail specification for general lighting and display applications*

IEC 62595-2-1:2016, *Display lighting unit - Part 2-1: Electro-optical measuring methods of LED backlight unit*

IEC 62607-3-1:2014, *Nanomanufacturing - Key control characteristics - Part 3-1: Luminescent nanomaterials - Quantum efficiency*

IEC TS 62607-3-3:2020, *Nanomanufacturing - Key control characteristics - Part 3-3: Luminescent nanomaterials - Determination of fluorescence lifetime of semiconductor quantum dots using time correlated single photon counting (TCSPC)*

IEC TS 62607-5-1:2014, *Nanomanufacturing - Key control characteristics - Part 5-1: Thin-film organic/nano electronic devices - Carrier transport measurements*

IEC TS 62607-6-8:2023, *Nanomanufacturing - Key control characteristics - Part 6-8: Graphene - Sheet resistance: In-line four-point probe*

IEC TS 62607-6-20:2022, *Nanomanufacturing - Key control characteristics - Part 6-20: Graphene-based material - Metallic impurity content: Inductively coupled plasma mass spectroscopy*

IEC 62899-203:2024, *Printed electronics - Part 203: Materials - Semiconductor ink*

IEC TR 63258:2021, *Nanotechnologies - A guideline for ellipsometry application to evaluate the thickness of nanoscale films*

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