IEC TS 62565-4-3

Edition 1.0 2026-06

TECHNICAL SPECIFICATION

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

ICS 07.120

ISBN 978-2-8327-1258-0

IEC TS 62565-4-3:2026-06(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2026 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms and definitions 8
3.1 General terms 8
3.2 Key control characteristics measured in accordance with this document 10
3.3 Abbreviated terms 12
4 General introduction regarding measurement methods 12
5 Recommended specification format for QLEDs 13
5.1 General product description 13
5.2 General procurement information 13
5.3 Key control characteristics for QD materials 14
5.4 Key control characteristics for QD inks 14
5.5 Key control characteristics for QD films 15
5.6 Key control characteristics for QLED prototype devices 15
6 Overview of test methods 15
Annex A (normative) KCC measurement procedures – supporting information 18
A.1 Single exciton lifetime: ultrafast spectroscopy 18
A.1.1 General 18
A.1.2 Measurement standard 18
A.1.3 Documented measurement procedure 18
A.2 Biexciton lifetime: ultrafast spectroscopy 18
A.2.1 General 18
A.2.2 Measurement standard 19
A.2.3 Documented measurement procedure 19
A.3 Positive trion lifetime: ultrafast spectroscopy 19
A.3.1 General 19
A.3.2 Measurement standard 19
A.3.3 Documented measurement procedure 19
A.4 Negative trion lifetime: ultrafast spectroscopy 19
A.4.1 General 19
A.4.2 Measurement standard 20
A.4.3 Documented measurement procedure 20
A.5 Emission wavelength: fluorescence spectrometer 20
A.5.1 General 20
A.5.2 Measurement standard 20
A.5.3 Documented measurement procedure 20
A.6 Photoluminescence quantum efficiency: fluorescence spectrometer 20
A.6.1 General 20
A.6.2 Measurement standard 21
A.6.3 Documented measurement procedure 21
A.7 Full width at half maximum: fluorescence spectrometer 21
A.7.1 General 21
A.7.2 Measurement standard 22
A.7.3 Documented measurement procedure 22

A.8 Colour coordinates: Colorimeter 22
A.8.1 General 22
A.8.2 Measurement standard 22
A.8.3 Documented measurement procedure 23
A.9 Chemical composition: ICP-MS 23
A.9.1 General 23
A.9.2 Measurement standard 23
A.9.3 Documented measurement procedure 23
A.10 Viscosity: viscosimeter 23
A.10.1 General 23
A.10.2 Documented measurement procedure 23
A.11 Wettability: contact angle measurement 24
A.11.1 General 24
A.11.2 Measurement standard 24
A.11.3 Documented measurement procedure 24
A.12 Surface tension: tensiometer 24
A.12.1 General 24
A.12.2 Documented measurement procedure 25
A.13 Photoluminescence quantum yield: fluorescence spectroscopy 25
A.13.1 General 25
A.13.2 Documented measurement procedure 25
A.14 Carrier mobility: Hall effect measurement 25
A.14.1 General 25
A.14.2 Documented measurement procedure 25
A.15 Sheet resistance: four-point probe method 26
A.15.1 General 26
A.15.2 Measurement standard 26
A.15.3 Documented measurement procedure 26
A.16 Film uniformity: ellipsometry 27
A.16.1 General 27
A.16.2 Documented measurement procedure 27
A.17 Film thickness: ellipsometry 27
A.17.1 General 27
A.17.2 Measurement standard 27
A.17.3 Documented measurement procedure 27
Annex B (informative) KCC measurement procedures – supporting information 28
B.1 Conduction band: UPS, fluorescence spectrometer 28
B.1.1 General 28
B.1.2 Documented measurement procedure 28
B.2 Valence band: UPS, fluorescence spectrometer 29
B.2.1 General 29
B.2.2 Documented measurement procedure 29
B.3 Core size and morphology: TEM 29
B.3.1 General 29
B.3.2 Measurement standard 30
B.4 Shell size and morphology: TEM 30
B.4.1 General 30
B.4.2 Measurement standard 30

B.5 Size distribution: TEM 31
B.5.1 General 31
B.5.2 Measurement standard 31
B.6 Surfactants: FTIR 31
B.6.1 General 31
B.6.2 Measurement standard 31
B.7 Crystallinity: P-XRD 32
B.7.1 General 32
B.7.2 Measurement standard 32
B.8 Solubility 32
B.8.1 General 32
B.8.2 Measurement standard 32
B.9 Transparency: UV-vis spectroscopy 33
B.9.1 General 33
B.9.2 Measurement standard 33
B.10 Fermi level: scanning Kelvin probe microscopy 34
B.10.1 General 34
B.10.2 Measurement standard 34
Bibliography 35

Figure A.1 – Sessile drop measurement method 24
Figure A.2 – The scheme of four-point probe 26

Table 1 – Format for general product description 13
Table 2 – Format for general procurement information 13
Table 3 – Key control characteristics for QD materials 14
Table 4 – Key control characteristics for QD inks 14
Table 5 – Key control characteristics for QD films 15
Table 6 – Key control characteristics for QLED prototype devices 15
Table 7 – Measurement methods of KCCs 16

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62565-4-3 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
113/956/DTS	113/975/RVDTS

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.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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*

ISO 15989:2004, *Plastics - Film and sheeting - Measurement of water-contact angle of corona-treated films*

OECD 114:2012, *Viscosity of Liquids*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

3.1 General terms

3.1.1
conduction band edge
minimum energy of the allowed energy band partially occupied by quasi-free electrons

Note 1 to entry: The electrons on conduction band are mobile and responsible for electric conductivity of QD film.

Note 2 to entry: Matching the conduction band of the electron transfer layer with that of QD film facilitates electron transfer.

[SOURCE: IEC 60050-113:2011, 113-06-20, modified – In the term, "edge" has been added. In the definition, "minimum energy of the" has been added. Notes 1 and 2 to entry have been added.]

3.1.2
valence band edge
maximum energy of the allowed energy band completely occupied by electrons at a thermodynamic temperature of zero kelvin

Note 1 to entry: Holes on valence band are mobile and responsible for hole conductivity of QD film.

Note 2 to entry: Matching the valence band of the hole transfer layer with that of QD film facilitates hole transfer.

[SOURCE: IEC 60050-113:2011, 113-06-19, modified – In the term, "edge" has been added. In the definition, "maximum energy of the" has been added, "band" has been replaced with "energy band", "completely" has been added, and "the valence electrons" has been replaced with "electrons". Notes 1 and 2 to entry have been added.]

3.1.3
single exciton lifetime
time it takes for an exciton to decay to the ground state

Note 1 to entry: Quantum lifetime is within the range of tens of nanoseconds.

Note 2 to entry: An exciton is a pair of electron and hole confined in QDs created by photo excitation or carrier injection.