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TECHNICAL SPECIFICATION

Nanomanufacturing – Material specifications –
Part 4-2: Luminescent nanomaterials – Detail specification for general lighting and display applications

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NANOMANUFACTURING – MATERIAL SPECIFICATIONS –

Part 4-2: Luminescent nanomaterials – Detail specification for general lighting and display applications

FOREWORD

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Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62565-4-2 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems.

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

Enquiry draft	Report on voting
113/361/DTS	113/417/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62565 series, published under the general title *Nanomanufacturing – Material specifications*, can be found on the IEC website.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Lighting devices and displays are transitioning from incandescent illumination sources based on heated filaments to solid-state lighting (SSL) sources. In devices such as lamps and luminaires used for general illumination, light emitting diodes (LED) form SSL sources that provide light, and a wide variety of lighting colours are commercially available. In display products such as liquid crystal devices, white backlights are used in conjunction with colour filters to provide red, green and blue colours, and these backlights are also increasingly leveraging breakthroughs in LED technologies to increase the colour gamut. There are several key drivers for this change including increased energy efficiency, increased product lifetime, flexibility in colours produced and good colour rendering properties. For example, solid-state lighting (SSL) sources can achieve luminous efficacies that are significantly higher than conventional incandescent lamps. Since approximately 20 % of the world's electricity consumption is attributed to providing illumination, the impact of such a large gain in luminous efficacy provided by changing to SSL technologies is significant. Likewise, SSL backlights consume less energy than other backlight technologies, which is especially important in battery powered portable electronics.

The structures of SSL sources used for general lighting and display backlights often are similar. In a common structure, these devices consist of a blue LED and at least one photoluminescent material to provide one or more additional wavelengths. When energized, some photons emitted by the LEDs are absorbed by the luminescent material and produce secondary photons of different wavelengths through the process of photoluminescence (PL). The light produced by the SSL source is a mixture of the emissions from the blue LED and the photoluminescent material. A variety of luminescent materials can be used in these applications including phosphors and luminescent nanomaterials.

Luminescent nanomaterials are comprised of semiconductor nanocrystals like spherical quantum dots and elongated quantum rods and inorganic nanophosphors. Semiconductor nanocrystals with sizes typically below 10 nm show size-tunable optical properties (size-dependent band gap and hence, size-dependent onset of absorption and spectral position of the emission band or emission colour) and electrochemical properties (size-dependent energetic positions of the valence and conduction band and hence, redox potentials of the charge carriers) due to particle size-dependent quantum confinement effects. Particularly favourable are their broad absorption bands (increasing absorption for all wavelengths shorter than the onset of absorption), their narrow emission bands, (often revealing a symmetric shape), their high photoluminescence quantum yields, and excellent photostability.

Light-emitting phosphors can also be used for lighting and display applications and in some instances phosphors with particle diameters less than 100 nm (i.e. nanoparticles) can be used. Such inorganic materials (also termed nanophosphors) include materials such as YAG:Ce. These nanophosphors are characterized by broad absorption bands, broad emission bands, good photoluminescence quantum efficiency, and a high photostability. The spectral position of the absorption and emission of inorganic nanophosphors is not affected by size, but the scattering properties will have a size dependence. However, the enhanced surface-to-volume ratio with decreasing particle size can favour luminescence quenching at surface defects, thereby affecting the photoluminescence quantum efficiency and PL decay behaviour and rendering both properties size-dependent.

Other nanomaterials like dye-doped or -labelled polymer nanoparticles, inorganic particles or hybrid organic–inorganic nanoparticles are commonly not used for such applications and are beyond the scope of this document.

Generally, luminescent nanomaterials used in lighting and display applications are classified according to excitation spectrum, emission spectrum (including a specific emission wavelength peak and a narrow emission peak shape as measured by the full-width at half maximum (FWHM)), quantum efficiency, chemistry and others. Generally, these properties are achieved in a monodisperse material, with particles of similar sizes (allowing for manufacturing tolerances). Imparting multiple colours to a lighting or display product may involve the use of nanomaterials of multiple sizes, each of which may be specified individually. As a result of the properties of luminescent nanomaterials, lighting and display devices incorporating these materials can have excellent luminous efficacy and extraordinary colour quality.

This document codifies the format for specifying, reporting, and validating the essential properties of luminescent nanomaterials for use in lighting and display products.

NANOMANUFACTURING – MATERIAL SPECIFICATIONS –

Part 4-2: Luminescent nanomaterials – Detail specification for general lighting and display applications

1 Scope

This part of IEC 62565, which is a Technical Specification, specifies the essential general and optical requirements of monodisperse luminescent nanomaterials used in general lighting and display products to enable their reliable mass production and quality control during the manufacturing process. This document does not address mixtures or agglomerations of luminescent nanomaterials.

In addition, this document enables the customer to specify requirements in a standardized manner and to verify through standardized methods that the luminescent nanomaterial meets the required properties.

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

IEC TS 62607-3-2, *Nanomanufacturing – Key control characteristics – Part 3-2: Luminescent nanoparticles – Determination of mass of quantum dot dispersion*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

3.1.1
absorption coefficient
corresponding absorbance divided by the optical path length through the sample

Note 1 to entry: For the purposes of this document, absorption coefficient is determined at a known concentration and at a wavelength where the impact of optical scattering is negligible.

3.1.2
colour
optical characteristic of a luminescent nanomaterial uniquely characterized by means of three coordinates in a colour space

Note 1 to entry: Examples of coordinates are the 1931 CIE tristimulus values and the CIELAB 1976 L*a*b* colour space.

Note 2 to entry: For determination of colour, it is also necessary to specify the illuminant (e.g. Illuminant A, Illuminant D65) and observer (e.g. 2° or 10°).

3.1.3
date of manufacture
date on which the luminescent nanomaterials were originally synthesized

3.1.4
emission spectrum
spectral distribution of the radiation emitted by a luminescent material for a specified excitation

[SOURCE: CIE S 017/E:2011, *ILV: International Lighting Vocabulary*, definition 17-380]

3.1.5
emission wavelength peak
wavelength at which the maximum emission occurs

3.1.6
emission wavelength range
range of wavelengths at which emission occurs

Note 1 to entry: To avoid contributions from stray light, the emission wavelength range is given at the wavelengths where the emission exceeds 5 % of the emission wavelength peak intensity.

3.1.7
excitation wavelength
specific wavelength used to stimulate a luminescent nanomaterial to emit light

3.1.8
FWHM
full-width at half maximum
range of emission wavelengths over which the emission spectrum intensity is greater than 50 % of its maximum value.

3.1.9
ID number
manufacturing process identifier (3.1.11) that uniquely identifies the specific synthesis procedure or recipe used to synthesize the luminescent nanomaterials

3.1.10
luminescent nanomaterial
nanomaterial which emits light when excited by electrical, optical or other type of excitation

EXAMPLE quantum dots, nanophosphors

3.1.11
manufacturing process identifier
unique means for identifying a manufacturing process, indicating a specific set of process parameters

3.1.12
nanomaterial
material with any external dimension in the nanoscale or having an internal structure or surface structure in the nanoscale

[SOURCE: ISO/TS 80004-1:2015, 2.4]

3.1.13
peak absorbance
wavelength at which maximum electromagnetic radiation absorption occurs

3.1.14
polarization anisotropy
emission anisotropy
r
polarization sensitivity of a fluorescent sample

Note 1 to entry: Polarization anisotropy is defined in terms of the measured fluorescence intensity in the directions parallel, $I_{\|}$, and perpendicular, $I_{\perp}$, to the plane of incidence, but compared to the total fluorescent intensity, I_{T}, where:

$$r = \frac{I_{\|} - I_{\perp}}{I_{\mathrm{T}}} = \frac{I_{\|} - I_{\perp}}{I_{\|} + 2I_{\perp}}$$

3.1.15
quantum efficiency
efficiency of photon emission from luminescent nanomaterials after excitation

[SOURCE: IEC 62607-3-1:2014, 3.13, modified – In the definition, "nanoparticles" has been replaced by "nanomaterials after excitation".]

3.2 Abbreviated terms

C_{pk}	manufacturing process capability index
CVD	chemical vapour deposition
DLS	dynamic light scattering
EDX	energy dispersive X-ray spectroscopy
ICP	inductively coupled plasma
IR	infrared spectroscopy
MS	mass spectrometry
NIR	near-infrared spectroscopy
OES	optical emission spectroscopy
PFS	polarized fluorescence spectroscopy
PL	photoluminescence
PVD	physical vapour deposition
SAXS	small angle X-ray scattering
SEM	scanning electron microscopy
TGA	thermogravimetric analysis
TOPO	trioctylphosphine oxide
TEM	transmission electron microscopy
UV-Vis	ultraviolet-visible spectroscopy
XRD	X-ray diffraction