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BSI Standards Publication

# Nanomanufacturing — Key control characteristics

## Part 7-2: Nano-enabled photovoltaics — Device evaluation method for indoor light



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# National foreword

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The UK participation in its preparation was entrusted to Technical Committee NTI/1, Nanotechnologies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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# TECHNICAL SPECIFICATION

## Nanomanufacturing – Key control characteristics –
## Part 7-2: Nano-enabled photovoltaics – Device evaluation method for indoor light

INTERNATIONAL
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CONTENTS

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# NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

## Part 7-2: Nano-enabled photovoltaics – Device evaluation method for indoor light

## FOREWORD

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IEC TS 62607-7-2 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 |
|---|---|
| 113/710/DTS | 113/737/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 of the IEC TS 62607 series, published under the general title *Nanomanufacturing – Key control characteristics*, can be found on the IEC website.

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

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- withdrawn,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

# INTRODUCTION

Commercialization of nano-enabled solar cells, such as organic solar cells, is being promoted by utilizing their advantages over conventional solar cells, such as light weight, flexibility, colour, transparency, and coating processability. Energy harvesting applications that generate power using indoor light have been recognized as important applications for nano solar cells in conjunction with recent advances in the Internet of Things. In general, nano solar cells have a large band gap and are suitable for power generation under indoor lighting whose spectra are localized in the visible light region. In addition, since the low illuminance characteristics can be improved by devising the configuration, it is expected to be suitable for energy harvesting using indoor light.

The IEC 60904 series specifies evaluation methods for sunlight. In IEC 60904, the most important factors in evaluating a solar cell are the selection of a light source and the method of adjusting its irradiance for measurement. By changing the light source from sunlight to indoor light, an evaluation method under indoor light can be obtained. The clause structure of this document corresponds to that of IEC 60904. While light sources are limited to sunlight in the outdoor environment, various light sources are used indoors, such as fluorescent lamps and LED lamps in addition to sunlight. The indoor brightness is expressed by illuminance in lux (lx), which takes into account the sensitivity of the human eye. Strictly speaking, since the spectral characteristics of the eyes are different from those of solar cells, there is not always a correlation between the illuminance and the power generation of solar cells. For example, a crystalline Si solar cell could generate power using only near-infrared light which is invisible to human eyes, i.e. zero lux. However, high-efficiency lighting other than incandescent lamps has a spectrum concentrated in the visible light region, thus expressing the efficiency of an indoor solar cell based on the spectrum of sunlight is not appropriate.

In this document, such uncertainties due to the use of illuminance instead or irradiance are eliminated by setting a reference spectrum for indoor light sources. The reference indoor light spectra are representatives of the spectrum of light sources used for indoor lighting, are defined only between 380 nm and 780 nm, and have no component outside of this wavelength range. Therefore, this document provides a method to evaluate solar cells with illuminance. Since the illuminance is obtained by the overlap integral of the spectral irradiance of the light source and the luminosity, there could be an infinite number of spectral irradiances that give the same illuminance. A large error could arise due to light in the wavelength region with low luminosity. In an extreme case, invisible light has a finite output even at zero illuminance. In this document, however, the output by zero lux illuminance is supposed to be zero, that is, the output is not guaranteed.

The target of this document is to define the output of a solar cell in a bright (finite illuminance) indoor environment. The output with light other than the reference spectrum is out of this target. If it is necessary to include such cases, they will be treated as individual cases. In that case, one would extend the reference spectrum and build an evaluation technique that uses irradiance instead of illuminance. Special illumination conditions can be used by using a user-defined reference spectrum. In this case, however, illuminance can be meaningless if the illumination contains a significant amount of invisible light.

Illumination includes not only the light that the eyes of humans are sensitive to, but also the infrared energy contained in incandescent lighting and sunlight that enters from outdoors. But because incandescent lighting is used less and less due to its poor energy efficiency, this document defines measurement methods with two standard indoor light sources specified by CIE: FL10 and LED-B4, corresponding to the fluorescent lamp and the white LED lamp, respectively, the correlated colour temperatures (CCT) of which are approximately 5 000 K. Other light sources such as sunlight or incandescent lamps are not appropriate because they contain much invisible infrared light and illuminance is not a good measure for performance evaluation of photovoltaic devices, because they contain a significant amount of invisible light.

This document, along with FL10 and LED-B4, establishes methods for evaluating photovoltaic cells under indoor conditions. This document assumes that an arbitrary photovoltaic cell will be measured under indoor lighting. For requirements not listed in this document, refer to the relevant normative references.

# NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

# Part 7-2: Nano-enabled photovoltaics – Device evaluation method for indoor light

## 1 Scope

This Technical Specification specifies the efficiency testing of photovoltaic cells (excluding multi-junction cells) under indoor light. Although it is primarily intended for nano-enabled photovoltaic cells (organic thin-film, dye-sensitized solar cells (DSC), and Perovskite solar cells), it can also be applied to other types of photovoltaic cells, such as Si, CIGS, GaAs cells, and so on.

## 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.

JIS C 1609-1, *Illuminance meters – Part 1: General measuring instruments*

DIN 5032-7, *Photometry – Part 7: Classification of illuminance meters and luminance meters*

ISO/CIE 19476, *Characterization of the performance of illuminance meters and luminance meters*

## 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**
**response time**
time required for current to respond after a change is made to the applied voltage

Note 1 to entry: Response time is represented by $\tau$ in the formula $I(t) = I(0) + \Delta I\left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$ for expressing change in current over time.

**3.2**
**indoor primary reference photovoltaic cell**
photovoltaic cell calibrated from a radiometer, standard detector, or standard indoor light that is traceable to SI units