

SEMI PV80-0622

SPECIFICATION OF INDOOR LIGHTING SIMULATOR REQUIREMENTS FOR EMERGING PHOTOVOLTAIC AND PEROVSKITE SOLAR CELL (PSC)

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1 Purpose

1.1 The International Commission on Illumination (CIE) has defined some lighting spectra for different indoor colorful applications and situations. However, the requirements for color testing do not apply to related indoor energy harvesting under different lighting uniformity and stability, for performance measurement of emerging photovoltaic (PV) and device. Furthermore, countless types of indoor lighting patterns are required to do performance characteristics measurement for different application contexts.

1.2 This activity shall develop a new specification of indoor lighting simulator requirement for performance measurement of emerging PV and device qualification.

1.3 The emerging PV includes DSSC, OPV, and PSC.

1.4 Indoor lighting simulator will address the performance of emerging PV device.

2 Scope

2.1 The proposed Standard aims to develop a durability test method to evaluate emerging PV. This activity will develop an evaluation principle and guide line for industries to follow and speed up the research for emerging PV products as well. This activity shall develop a new specification of indoor lighting simulator requirements for performance measurement of emerging PV and device qualification. The objective is to focus on specification of indoor lighting, and provides some actions as below:

2.1.1 Define the specific spectrum of indoor lighting simulator.

2.1.2 Define the classification of indoor lighting simulator.

2.2 For other PV technologies, the proposed qualification would be helpful to refer to in similar low light application like emerging PV.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Standard does not specify any kind of sample specification for emerging PV; for example, $1 \times 1 \text{ cm}^2$, $1 \times 5 \text{ cm}^2$, $2 \times 5 \text{ cm}^2$, $10 \times 10 \text{ cm}^2$.

3.2 The test is to determine the electrical and thermal characteristics of test sample, and to work within reasonable constraints of cost and time if possible. Test sample needs to be capable of withstanding prolonged exposure within climates described in the scope. The actual lifetime for test modules to be qualified will depend on product's design, environment and operated conditions.

3.3 Emerging PV shall need specific basis of reference to differ with SRC condition used by *p-n* junction solar cell, and make reserves extra time for I-V test due to capacitance effect.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI PV57 — Test Method for Current-Voltage (I-V) Performance Measurement of Organic Photovoltaic (OPV) and Dye-Sensitized Solar Cell (DSSC) and Perovskite Solar Cell (PSC)

SEMI PV69 — Test Method for Spectrum Response (SR) Measurement of Organic Photovoltaic (OPV) and Dye-Sensitized Solar Cell (DSSC) and Perovskite Solar Cell (PSC)

4.2 CIE Standards¹

CIE 063-1984 — The Spectroradiometric Measurement of Light Sources

CIE S 014-2/E:2006/ISO 11664-2:2007(E) — CIE Standard Illuminants for Colorimetry

CIE ISO/CIE 19476:2014 — Characterization of the Performance of Illuminance Meters and Luminance Meters

4.3 IEC Standards²

IEC 60410:1973 (Withdrawn) — Sampling Plans and Procedures for Inspection by Attributes

IEC 60904-3:2016 — Photovoltaic Devices – Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) Solar Devices with Reference Spectral Irradiance Data

IEC 60904-9:2007 — Photovoltaic Devices – Part 9: Solar Simulator Performance Requirements

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *CI* — control interface

5.1.2 *DSSC* — dye-sensitized solar cell

5.1.3 *DUT* — device under test

5.1.4 *ILS* — indoor lighting simulator

5.1.5 *IPCE* — incident photon-electron conversion efficiency

5.1.6 *ITP* — isothermal test plane

5.1.7 *LM* — lux meter

5.1.8 *OPV* — organic photovoltaic

5.1.9 *PSC* — perovskite solar cell

5.1.10 *RD* — reference device

5.1.11 *RSD* — relative standard deviation

5.1.12 *SMU* — source measurement unit

5.1.13 *SRC* — standard reporting condition

5.1.14 *SS* — solar simulator

5.1.15 *STC* — standard test condition

5.1.16 *TM* — temperature monitor

5.2 Definitions

5.2.1 *cell* — test sample assembled should be included seal, and package.

5.2.2 *cell temperature* — the temperature (°C) of cell.

5.2.3 *emerging PV* — the PV devices include DSSC, OPV, and PSC.

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² International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.919.02.11, Fax: +41.22.919.03.00, <http://www.iec.ch>

5.2.4 *isothermal test plane* — the isothermal plane is intended to contain DUT at the reference irradiance level.

5.2.5 *I-V* — the current-voltage curve of test sample is the superposition of the curve with the light/dark-generated current.

5.2.6 *light source* — a source of radiant energy to simulate indoor lighting application and used for DUT performance measurement.

5.2.7 *module* — test sample assembled should be included seal, package, the least two cells than one and four well-attached wires (or terminal wires). Terminal wires are used to multiply set designed for the safety of the rated current, and length is 5 cm.

5.2.8 *monitor photo-detector* — a photo detector incorporated into the optical system to monitor the amount of light reaching the device under test, enabling adjustments to be made to accommodate varying light intensity.

5.2.9 *standard reporting condition (SRC)* — standard reporting conditions for test sample, which is defined by temperature, spectral irradiance, and total irradiance. The term reporting, rather than reference or test, is used because a measurement can be performed at conditions other than SRC and then carefully corrected to be equivalent to being measured at SRC (e.g., Illuminant A, 25°C, 1000 lx).

5.2.10 *standard test condition (STC)* — standard test conditions for test sample. Sample temperature: 25°C, Spectral irradiance: AM1.5G, Irradiance: 1000 W·m⁻².

5.2.11 *test sample* — test device of emerging PV or OPV/DSSC/PSC.

5.3 Symbols

5.3.1 *A* — cell area (cm²).

5.3.2 *E* — irradiance (mW·cm⁻²).

5.3.3 *I* — current (mA).

5.3.4 *I_{sc}* — short-circuit current (mA).

5.3.5 *MMF* — mismatch factor.

5.3.6 *T* — temperature (°C).

5.3.7 *V* — voltage (V).

6 Calculations

6.1 For the test sample, the shape of the I-V characteristic depends on the short-circuit current and the device temperature, but not on the spectrum used to generate the short-circuit current. For these devices, the correction of spectrum mismatch or spectral response mismatch is possible using the following procedure (refer to SEMI PV57 and SEMI PV69). For other devices, a measurement of the I-V characteristic in using a light source with the appropriate spectrum. A correction is not necessary either if the test spectrum is identical to the reference spectrum (refer to CIE ISO/CIE 19476) or if the relative spectral response of test sample is identical to the reference cell relative spectral response. The reading as obtained from the reference cell specifies which intensity of the reference spectrum will generate the same short-circuit current in the test sample as the test spectrum. If there is a mismatch between both spectra and spectral responses, then a mismatch correction should be calculated.

6.2 RSD is defined as Equation 1:

$$RSD (\%) = \frac{\text{standard deviation}}{\text{average}} \times 100\% \quad (1)$$

6.3 The non-uniformity is defined as Equation 2, max and min is symbol of detector signal:

$$\text{Non - Uniformity} (\%) = \frac{(\text{max} - \text{min})}{(\text{max} + \text{min})} \times 100\% \quad (2)$$

7 Apparatus

7.1 Reference Device (RD)

7.1.1 The reference photodetector's calibration must be traceable to SI units through a 3rd party lab spectral responsivity scale or other relevant radiometric and lx scale. The calibration mode of the photodetector (irradiance or power) will affect the procedures used, and the kinds of measurements performed.

7.1.2 The following detectors are acceptable for the calibration of the monochromatic light source:

7.1.2.1 Pyroelectric radiometer, and

7.1.2.2 Cryogenic radiometer, and

7.1.2.3 Spectrally calibrated photodiode, photodiode irradiance detector, or solar cell, calibrated in power or irradiance mode. It should have calibration data that includes the entire spectral response range of the device to be tested. If a part of the range is omitted, it will limit the spectral range of the results of this test, causing an error in computing the spectral mismatch parameter.

7.1.2.4 Reference device is calibrated using by illuminant A reference to the same desired reference spectral irradiance distribution.

7.1.2.5 Report need to commit traceability including measurement of lux, linearity and irradiance, which are determined in accordance with CIE ISO/CIE 19476 and CIE 063.

8 Test Procedures

8.1.1 The work includes visual inspection, warm up system, spectral match, non-uniformity and temporal instability. There are three items (e.g., spectral match, non-uniformity and temporal instability) of test samples fulfill the qualification test sequences listed in Figure 1.

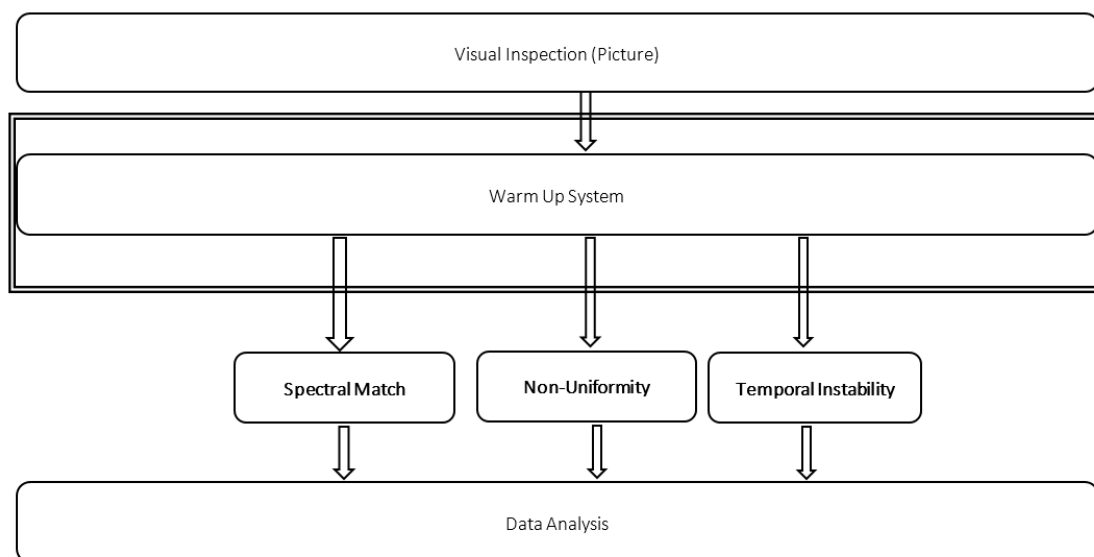


Figure 1
Test Sequence

8.1.2 *Visual Inspection* — Each system to determine the presence or absence of anomalies or defects. Optical magnification is not required. Apparatus for carefully inspect each test sample under an illumination of not less than 1,000 lx for the visual check.

8.1.3 *Spectral Match* — Available methods are the use of spectroradiometer. Standard lighting spectrum is defined by the deviation from Appendix 2 as laid down in CIE (refer to § 4.2). For three wavelength intervals of interest, the