SEMI PV89-0219
TEST METHOD OF CURRENT-VOLTAGE (I-V) MEASUREMENT IN INDOOR LIGHTING FOR DYE-SENSITIZED SOLAR CELL AND ORGANIC PHOTOVOLTAIC

This Standard was technically approved by the Photovoltaic Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on October 19, 2018. Available at www.semiviews.org and www.semi.org in February 2019.

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1 Purpose

1.1 This Document provides test method for organic photovoltaic (OPV) and dye-sensitized solar cell (DSC) device over a range of temperature and intensity conditions for different indoor lighting, and without hysteresis phenomenon due to capacity effect. The work includes characterizing spectral and angular effects, definition of temperature and light intensity indoors, evaluating instantaneous P_{max}, and stating result in the form of a numerical rating.

1.2 This Test Method is for current-voltage (I-V) measurement in indoor lighting for OPV/DSC.

2 Scope

2.1 This Test Method is for I-V performance measurement of OPV/DSC in indoor lighting and device qualification. The objective is to focus on specification of indoor lighting, and provides some actions as below.

2.2 To define the requirement of equipment for OPV/DSC performance measurement indoors.

2.3 To define the specific measurement condition for OPV/DSC indoors.

2.4 For other PV technologies, the proposed qualification would be helpful to refer to in similar low light application like OPV/DSC.

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 Document does not specify any kind of sample specification for OPV/DSC; for example, 1 × 1 cm^2, 1 × 5 cm^2, 2 × 5 cm^2, 10 × 10 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 OPV/DSC 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)

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

SEMI PV80 —— Specification of Indoor Lighting Simulator Requirements for Emerging Photovoltaic

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4.2 *CIE Standards*[1]

CIE S 014-2 — CIE Colorimetry – Part 2: Standard Illuminants for Colorimetry

CIE S 023 — Characterization of the Performance of Illuminance Meters and Luminance Meters

CIE 63 — The Spectroradiometric Measurement of Light Sources

4.3 *IEC Standards*[2]

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

IEC 60904-9 — 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 *DUT* — device under test

5.1.3 *DSC* — dye-sensitized solar cell

5.1.4 *ILS* — indoor lighting simulator

5.1.5 *ITP* — isothermal test plane

5.1.6 *LM* — lux meter

5.1.7 *OPV* — organic photovoltaic

5.1.8 *PSC* — perovskite solar cell

5.1.9 *RD* — reference device

5.1.10 *RSD* — relative standard deviation

5.1.11 *SMU* — source measurement unit

5.1.12 *SS* — solar simulator

5.1.13 *SRC* — standard reporting condition

5.1.14 *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 DSC, OPV and PSC.

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.

[1] International Commission on Illumination, CIE Central Bureau, Babenbergerstasse 9/9A, 1010 Vienna, Austria. Telephone: +1.43.1.714.31.87, http://www.cie.co.at

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

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5.2.7 *indoor lighting STC* — standard test conditions for test sample. Sample temperature: 25°C, Spectral irradiance: Illuminant A, Irradiance: 1,000 lx.

5.2.8 *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.

5.2.9 *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.

5.2.10 *Perovskite solar cell* — the structural design of perovskite solar cell is considered to be the extension of DSC or OPV devices.

5.2.11 *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, 1,000 lx).

5.2.12 *sweep direction* — defined in direction either from I_{sc} to V_{oc} (forward) or V_{oc} to I_{sc} (backward).

5.2.13 *test sample* — test device of emerging PV or OPV/DSC/PSC.

5.3 *Symbols*

5.3.1 A — cell area (cm^2)

5.3.2 E — irradiance ($mW \cdot cm^{-2}$)

5.3.3 I — current (mA)

5.3.4 Isc — 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 (see CIE S 023) 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.

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

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

$$Non-uniformity(\%) \equiv \frac{(max-min)}{(max+min)} \times 100\% \quad (2)$$

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.

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