SEMI PV57-1214 (Reapproved 0820)
TEST METHOD FOR CURRENT-VOLTAGE (I-V) PERFORMANCE MEASUREMENT OF ORGANIC PHOTOVOLTAIC (OPV) AND DYE-SENSITIZED SOLAR CELL (DSSC)

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1 Purpose

1.1 This Standard proposes a performance test method for organic photovoltaic (OPV)/dye sensitized solar cell (DSSC) according to its current-voltage (I-V) measurement and device qualification.

1.2 The major difference between OPV/DSSC and *p-n* junction solar cells is photoelectric conversion mechanism, such as:

1.2.1 The operation principle of OPV/DSSC uses layers of organic molecules subject to lighting after excitation electronic, then passes to the inorganic/organic layer of the wide energy gap nano-layer and voltage.

1.2.2 OPV/DSSC has a different spectrum and absorption range with *p-n* junction than solar cell does.

1.2.3 OPV/DSSC needs more photoelectric conversion response time caused by specific material properties.

1.3 Therefore, OPV/DSSC shall need specific basis of reference to differ with standard test condition (STC) [AM 1.5G, 25°C, 1000 $W.m^{-2}$] used by *p-n* junction solar cell, and also make corrections for spectral issue and reserves extra time for I-V test due to capacitance effect.

2 Scope

2.1 This Standard shall develop a performance test method for OPV/DSSC according to its I-V measurement and device qualification. The objective is to focus on OPV/DSSC I-V performance evaluation either indoors or outdoors, and provide some actions as below.

2.1.1 Define the specific STC (see ¶¶ 5.2.8 and 5.2.9) for OPV/DSSC when indoors.

2.1.2 Provide both statistic method (see § 8) and testing procedures (see § 9) for OPV/DSSC to reduce measurement errors due to capacitive effect.

2.1.3 Evaluate the relationship (see Figure 4) between short-circuit current (I_{sc}) and spectral correction factor (MMF).

2.1.4 Approach specific diffuse lighting application when indoors or outdoors.

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3 Limitations

3.1 This Document does not specify any kind of sample specification for OPV/DSSC; for example, 1 × 1 cm^2, 1 × 5 cm^2, 2 × 5 cm^2, 1 × 10 cm^2, etc.

3.2 I-V performance measurement method does not provide the specifications of I-V sweep by setting delay time but the test time should be considered.

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4 Referenced Standards and Documents

4.1 *IEC Standards*[1]

IEC 60410 — Sampling Plans and Procedures for Inspection by Attributes

IEC 60904-1 — Photovoltaic Devices – Part 1: Measurements of Photovoltaic Current-Voltage Characteristics

IEC 60904-2 — Photovoltaic Devices – Part 2: Requirements for Reference Solar Devices

IEC 60904-6 — Photovoltaic Devices – Part 6: Requirements for Reference Solar Modules

IEC 60904-7 — Photovoltaic Devices – Part 7: Computation of Spectral Mismatch Correction for Measurements of Photovoltaic Devices

IEC 60904-10 — Photovoltaic Devices – Part 10: Methods of Linearity Measurement

4.2 *ISO Standards*[2]

ISO/IEC 17025 — General Requirements for the Competence of Testing and Calibration Laboratories

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 *IPCE* — incident photon-electron conversion efficiency

5.1.5 *ITP* — isothermal test plane

5.1.6 *I-V* — current-voltage

5.1.7 *OPV* — organic photovoltaic

5.1.8 *RD* — reference device

5.1.9 *RSD* — relative standard deviation

5.1.10 *TM* — temperature monitor

5.1.11 *SMU* — source measurement unit

5.1.12 *SR* — spectral response

5.1.13 *SS* — solar simulator

5.1.14 *STC* — standard test condition

5.1.15 *ULIC* — ultra low irradiance condition

5.1.16 *VLIC* — very low irradiance condition

5.2 *Definitions*

5.2.1 *cell temperature* — the temperature (°C) of solar cell.

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

[1] 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

[2] International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, http://www.iso.org

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5.2.3 *light source* — a source of radiant energy to simulate natural sunlight and used for cell performance measurement.

5.2.4 *performance data* — P_{max}, V_{oc}, I_{sc}, FF, η.

5.2.5 *standard test conditions (STC)* — for solar cell. Cell temperature: 25°C, AM 1.5G, Irradiance: 1000 $W.m^{-2}$.

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

5.2.7 *test sample* — test device of OPV/DSSC.

5.2.8 *ultra low irradiance condition (ULIC)* — for OPV/DSSC. Cell temperature: 25°C, AM 1.5G, Irradiance: 1 $W.m^{-2}$.

5.2.9 *very low irradiance condition (VLIC)* — for OPV/DSSC. Cell temperature: 25°C, AM 1.5G, Irradiance: 60 $W.m^{-2}$.

5.3 *Symbols*

5.3.1 A — cell area (m^2).

5.3.2 α — temperature coefficient ($°C^{-1}$).

5.3.3 E — irradiance ($W.m^{-2}$).

5.3.4 η — efficiency (%).

5.3.5 FF — fill factor (%).

5.3.6 I — current (A).

5.3.7 I_{sc} — short-circuit current (A).

5.3.8 MMF — spectral mismatch parameter (or factor).

5.3.9 P_{max} — maximum power (W).

5.3.10 R_s — series resistance (Ω).

5.3.11 R_{sh} — shunt resistance (Ω).

5.3.12 T — temperature (°C).

5.3.13 V — voltage (V).

5.3.14 V_{oc} — open-circuit voltage (V).

6 Apparatus

6.1 Apparatus includes reference device (RD), temperature monitor (TM), source measurement unit (SMU), isothermal test plane (ITP), solar simulator (SS) [see Figure 1].

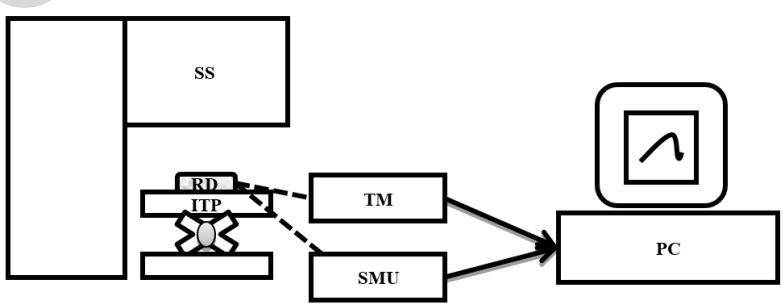

Figure 1
Testing Setup Equipment Diagrammatic Sketch

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6.2 *RD*

6.2.1 RD is calibrated indoors using simulated sunlight or outdoors in natural sunlight by reference to the same desired reference spectral irradiance distribution.

6.2.2 Report need to commit traceability including measurement of I-V, SR and IPCE, which are determined in accordance with IEC 60904-2.

6.3 *TM*

6.3.1 TM shall record both the cell temperature and test plane temperature simultaneously while I-V is measured, and its accuracy need keep within ±0.5°C.

6.4 *SMU*

6.4.1 SMU is used to measure current and voltage through DUT by using a voltage sweep with numerous steps (see ¶ 9.7) to build I-V curve.

6.5 *ITP*

6.5.1 ITP intended to contain DUT at the reference irradiance level (see ¶ 9.7), and control test cell keep temperature within 25 ± 1°C.

6.6 *SS*

6.6.1 SS may be one of three classes (A, B, or C) for each of the three categories includes spectral match, spatial nonuniformity and temporal instability. Each simulator is rated with three letters in order of spectral match, nonuniformity of irradiance in the test plane and temporal instability (e.g., CBA). Solar simulators for irradiance exposure should at least fulfill class BBA requirements, and class AAA is better for long term instability issue.

6.6.2 Test plane should be intended to fully contain all the area of test device.

6.6.3 Report need to commit traceability include measurement of spectral match, uniformity and temporal instability.

7 Preconditioning and Conditioning

7.1 *DSSC and OPV Samples (see Figures 2 and 3)*

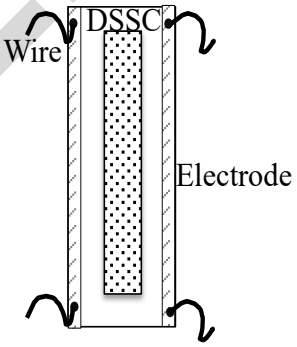

Figure 2
DSSC Sample Diagrammatic Sketch

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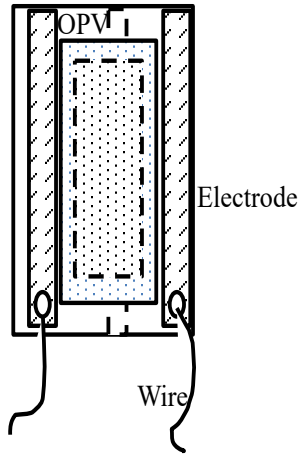

Figure 3
OPV Sample Diagrammatic Sketch

7.1.1 Five test samples, which are made by same raw materials and process, are required at least. General test sample assembled should be including seal, package and four well-attached wires (or terminal wires). Terminal wires are used multiply set designed for the safety of the rated current and length is 5 cm.

7.1.2 Relative performance data is defined as Equation 1 for test samples, and shall keep 90% at least in one month after pre-test.

$$Relative\ Performance\ data(\%) \equiv \frac{(Final - Initial)}{Initial} \times 100\% \quad (1)$$

7.2 *RD*

7.2.1 Calibration for the secondary photovoltaic reference cell should consists of short-circuit current (I_{sc}) under natural or simulated sunlight, by using a primary reference cell to measure the incident irradiance (E_i).

7.2.2 Reference cell is important during calibration for solar simulator, which is required long-term stability for frequent calibrations. Until now, a test sample matching such requirements has rarely been found. Therefore, a crystalline silicon (c-Si) solar cell with long-term stability is generally used as an alternative (see Table 1).

Table 1 Filtered c-Si Reference Cell (see ¶¶ 10.7 and 10.9)

Windows with Filter Type	*Applied Type*
Si + BK7 or Quartz	Monocrystalline Si (c-Si)
Si + BK7 or Quartz	Polycrystalline Si (mc-Si)
Si + BK7 or Quartz with KG2	Amorphous Si (a-Si)
Si + BK7 or Quartz with KG3	DSSC with N749
Si + BK7 or Quartz with KG5	DSSC with N719, and OPV with polymer

7.2.3 Calibrations for the filtered reference cell should consist of short-circuit current (I_{sc}) and incident irradiance (E_i). In addition, the relative spectral response of cell needs be calibrated to determine the relative spectral irradiance of the light source as well. Errors in the short-circuit current, due to both spectral irradiance of light source and spectral response of primary reference cell, are then corrected by dividing the short-circuit current and the spectral mismatch parameter. Also, if the cell temperature is out of 25 ± 1°C, then temperature coefficient (α) of short-circuit current (I_{sc}) should be needed.

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