

SEMI PV76-0117

TEST METHOD FOR DURABILITY OF LOW LIGHT INTENSITY ORGANIC PHOTOVOLTAIC (OPV) AND DYE-SENSITIZED SOLAR CELL (DSSC)

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1 Purpose

1.1 This Standard provides a durability test method for organic photovoltaic (OPV)/dye-sensitized solar cell (DSSC) according to its design qualification.

1.2 The major difference between OPV/DSSC and *p-n* junction solar cell is photoelectric conversion mechanism, such as with a period.

1.2.1 The operation principle of OPV/DSSC is using layers of organic molecules subject to lighting after excitation electrons then pass to the inorganic/organic layer of the wide energy gap nano-layer and voltage.

1.2.2 Environmental degradation factors (humidity, temperature, light) will address the performance and reliability for OPV/DSSC device.

2 Scope

2.1 The Standard aims to develop a durability test method to evaluate OPV/DSSC. This activity will develop an evaluation principle and guideline for industries to follow and speed up the research for OPV/DSSC products as well:

2.1.1 To evaluate OPV/DSSC performance during a light soaking test.

2.1.2 To evaluate OPV/DSSC performance during a thermal cycle test.

2.1.3 To evaluate OPV/DSSC performance during a damp heat test.

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

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/DSSC, for example: $1 \times 1 \text{ cm}^2$, $1 \times 5 \text{ cm}^2$, $2 \times 5 \text{ cm}^2$, $1 \times 10 \text{ cm}^2$, etc.

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 Therefore, OPV/DSSC shall need specific basis of reference to differ with standard reporting conditions (SRC) used by *p-n* junction solar cell, and make reserves extra time for current-voltage (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)

4.2 IEC Standards¹

IEC 60068-2-78 — Environmental Testing – Part 2-78: Tests – Test Cab: Damp Heat, Steady State

IEC 60410 — Sampling Plans and Procedures for Inspection by Attributes

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

IEC 60904-3 — Photovoltaic Devices – Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) 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 *DSSC* — dye-sensitized solar cell

5.1.4 *IPCE* — incident photon-electron conversion efficiency

5.1.5 *ITP* — isothermal test plane

5.1.6 *OPV* — organic photovoltaic

5.1.7 *RD* — reference device

5.1.8 *RSD* — relative standard deviation

5.1.9 *SMU* — source measurement unit

5.1.10 *SS* — solar simulator

5.1.11 *SRC* — standard reporting conditions

5.1.12 *STC* — standard test conditions

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

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

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

5.2.6 *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.

5.2.7 *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.

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5.2.8 *standard reporting conditions (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., AM 1.5G, 25°C, 300 W·m⁻²). As a matter of shorthand, the global and direct terrestrial reference spectra is often referred to as AM 1.5G and AM 1.5D, respectively.

5.2.9 *standard test conditions (STC)* — standard test conditions for test sample. Sample temperature: 25°C, Spectral irradiance: AM 1.5G, Irradiance: 1000 W·m⁻².

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

5.3 Symbols

5.3.1 A — cell area (m²)

5.3.2 E — irradiance (W·m⁻²)

5.3.3 I — current (A)

5.3.4 I - V — current-voltage

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

5.3.6 MMF — spectral mismatch parameter (or factor)

5.3.7 T — temperature (°C)

5.3.8 V — voltage (V)

6 Summary of Test Method

6.1 The work includes light soaking, thermal cycle, damp heat, and combine thermal cycle and damp heat. There are five groups of test samples fulfill the qualification test sequences list in Figure 1. Each box refers to the corresponding subsection in this Standard. Test procedures and severities, including initial and final I-V measurements in § 10.

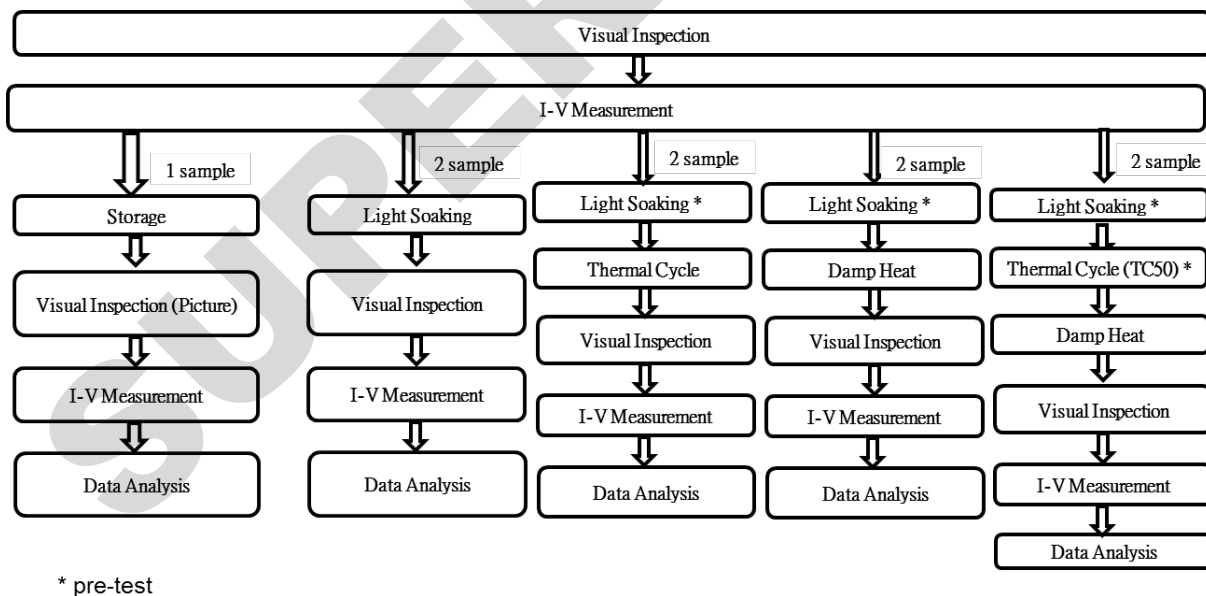


Figure 1
Qualification Test Sequence

7 Apparatus

7.1 Sampling

7.1.1 Nine samples (include one control sample, eight test samples) for qualification testing shall be taken at random from a production batch or batches, in accordance with the procedure given in IEC 60410. The modules shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets; have been subjected to the manufacturer's normal inspection, quality control and production acceptance procedures. The test sample shall be complete in every detail and accompanied by the manufacturer's handling, mounting and connection instructions, including the maximum permissible rated specification (i.e., V_{oc} , I_{sc} , etc.).

7.2 Testing Setup Equipment

7.2.1 Visual Inspection, each device under test (DUT) 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.

7.2.2 I-V measurement, to determine the maximum power of the DUT before and after the various environmental tests. Repeatability of the test is the most important factor. Apparatus for measuring an I-V curve in accordance with SEMI PV57.

7.2.3 Light soaking, to stabilize the electrical characteristics of thin-film modules by means of simulated solar irradiation. Apparatus for the following:

7.2.3.1 A class CCC solar simulator, in accordance with the IEC 60904-9.

7.2.3.2 A suitable reference device, with integrator, for monitoring the irradiation.

7.2.3.3 Means to mount the DUT, as recommended by the manufacturer, co-planar with the reference device.

7.2.3.4 Means for measuring the temperature of the DUT to an accuracy of $\pm 1^\circ\text{C}$.

7.2.3.5 Resistive loads sized such that at standard test conditions (STC) the modules will operate near their maximum power.

7.2.4 Thermal cycle, to determine the ability of the DUT to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature. Apparatus for the following:

7.2.4.1 A climatic chamber with automatic temperature control means for circulating the air inside and means to avoid condensation on the DUT during the test, capable of subjecting one or more DUT to the thermal cycle.

7.2.4.2 Means for mounting or supporting the DUT in the chamber, to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the DUT is thermally isolated.

7.2.4.2.1 Means for measuring and recording the temperature of the DUT to an accuracy of $\pm 1^\circ\text{C}$.

7.2.4.2.2 Means for monitoring, throughout the test, the continuity of the internal circuit of each DUT.

7.2.5 Damp heat, to determine the ability of the DUT to withstand the effects of long-term penetration of humidity. Apparatus for following:

7.2.5.1 A climatic chamber with automatic temperature control means for circulating the air inside and means to avoid condensation on the DUT during the test.

7.2.5.2 Means for mounting or supporting the DUT in the chamber, to allow free circulation of the surrounding air. The thermal and humidity conduction of the mount or support shall be low, so that, for practical purposes, the DUT is thermally and humidity isolated.

7.2.5.2.1 Air temperature throughout the working volume shall be within $\pm 2^\circ\text{C}$ of that specified.

7.2.5.2.2 Relative humidity shall be controlled within $\pm 5\%\text{RH}$ of that specified.

7.3 Reference Device (RD)

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

7.3.2 Report need to commit traceability including measurement of I-V, SR and incident photon-electron conversion efficiency (IPCE), which are determined in accordance with IEC 60904-2.

8 Preconditioning and Conditioning

8.1 Test samples refer to SEMI PV57, ¶ 7.1.

8.1.1 Nine test samples 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 used to multiply set designed for the safety of the rated current, and length is 5 cm.

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

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

8.2 RD

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

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

8.2.2.1 Pyroelectric radiometer, and

8.2.2.2 Cryogenic radiometer, and

8.2.2.3 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.

8.3 Test sample's design shall be judged to have passed the qualification tests, if each test sample meets all the following criteria:

8.3.1 The pass/fail criteria must consider the laboratory uncertainty of the measurement. As an example, if the laboratory extended uncertainty, 2 sigma of the STC or SRC measurement, is $\pm 5\%$, then a maximum power measurement greater than 85.5% of the minimum specified value would be the pass criteria.

8.3.2 After the final light soaking, the maximum output power at STC or SRC is not less than 90% of the minimum value.

8.3.3 No sample has exhibited any open-circuit during the tests.

8.3.4 There is no visual evidence of a major defect, as defined in § 10.3.

8.3.5 If two or more test samples do not meet these test criteria, the design shall be deemed not to have met the qualification requirements. Should one test sample fail any test, another two test samples meeting the requirements of § 7.1 shall be subjected during the whole of the relevant test sequence from the beginning. If one or both of these test samples also fail, the design shall be deemed not to have met the qualification requirements. If, however, both test samples pass the test sequence, the design shall be judged to have met the qualification requirements.

9 Calculations

9.1 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 IEC 60904-3) 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.