Background Statement for SEMI Draft Document 5598A
NEW STANDARD: TEST METHOD FOR DURABILITY OF LOW LIGHT INTENSITY ORGANIC PHOTOVOLTAIC (OPV) AND DYE-SENSITIZED SOLAR CELL (DSSC)

Notice: This background statement is not part of the balloted item. It is provided solely to assist the recipient in reaching an informed decision based on the rationale of the activity that preceded the creation of this document.

Notice: Recipients of this Document are invited to submit, with their comments, notification of any relevant patented technology or copyrighted items of which they are aware and to provide supporting documentation. In this context, “patented technology” is defined as technology for which a patent has issued or has been applied for. In the latter case, only publicly available information on the contents of the patent application is to be provided.

Background Statement:
The current technology challenge for OPV/DSSC products still focused on a serious packaging problem that certainly appears in subtropical environments. Some stability issues relate to the erosion of the glass adhesion failure, the barrier gas and barrier water, etc. In general, environmental degradation factors (humidity, temperature, pressure, light) will seriously affect OPV/DSSC device performance and reliability, and shorten its lifetime. Therefore, this activity shall develop a durability test method to evaluate OPV/DSSC. This activity will also develop a principal and guild line for OPV/DSSC industries to follow in the coming future, and speed up the packaging design of OPV/DSSC products as well.

Review and Adjudication Information

<table>
<thead>
<tr>
<th>Group</th>
<th>Task Force Review</th>
<th>Committee Adjudication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>TBD</td>
<td>Oct 21, 2016</td>
</tr>
<tr>
<td>Time &amp; Time zone</td>
<td>TBD</td>
<td>13:30~15:00</td>
</tr>
<tr>
<td>Location</td>
<td>ITRI</td>
<td>ITRI</td>
</tr>
<tr>
<td>City, State/Country</td>
<td>Hsinchu, Taiwan</td>
<td>Hsinchu, Taiwan</td>
</tr>
<tr>
<td>Leader(s)</td>
<td>D.R. Huang (NDHU)</td>
<td>B.N. Chuang (ITRI)</td>
</tr>
<tr>
<td></td>
<td>Anderson Hsu (ITRI)</td>
<td>JS Chen (Tera Solar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ray Sung (UL Taiwan)</td>
</tr>
<tr>
<td>Standards Staff</td>
<td>Dean Chang (<a href="mailto:dchang@semi.org">dchang@semi.org</a>)</td>
<td>Dean Chang (<a href="mailto:dchang@semi.org">dchang@semi.org</a>)</td>
</tr>
<tr>
<td></td>
<td>SEMI Taiwan</td>
<td>SEMI Taiwan</td>
</tr>
</tbody>
</table>

This meeting’s details are subject to change, and additional review sessions may be scheduled if necessary. Contact Standards staff for confirmation.

Telephone and web information will be distributed to interested parties as the meeting date approaches. If you will not be able to attend these meetings in person but would like to participate by telephone/web, please contact Standards staff. Check www.semi.org/standards on calendar of event for the latest meeting schedule.

If you need further assistance, or have questions, please do not hesitate to contact the Organic and Dye Sensitized Solar Cell Task Force:

D. R. Huang, derry@mail.ndhu.edu.tw
Anderson S. T. Hsu, andersonhsu@itri.org.tw
SEMI Draft Document 5598A

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

1 Purpose
1.1 This standard provides durability test method for OPV/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 proposed standard aims to develop a durability test method to evaluate OPV/DSSC. This activity will develop an evaluation principle and guild line 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, e.g. 1x1 cm², 1x5 cm², 2x5 cm², 1x10 cm², 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 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
SEMI PV57 – Test Method for Current-Voltage (I-V) Performance Measurement of Organic Photovoltaic (OPV) and Dye-Sensitized Solar Cell (DSSC)

4.2 IEC Standards

IEC 60410 – Sampling plans and procedures for inspection by attributes
IEC 60904-2 – Photovoltaic devices – Part 2: Requirements for reference solar devices
IEC 60904-4 – Photovoltaic devices - Part 4: Reference solar devices - Procedures for establishing calibration traceability
IEC 60904-9 – Photovoltaic devices – Part 9: Solar simulator performance requirements
IEC 61646 – Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 60068-1 – Environmental testing – Part 1: General and guidance
IEC 60068-2-78 – Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state
IEC 60721-2-1 – Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Temperature and humidity

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 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.

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

5.2.9 **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 (ex. 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 AM1.5G and AM1.5D, respectively.

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 **Iₛ** — short-circuit current (A)

5.3.5 **MMF** — spectral mismatch parameter (or factor)

5.3.6 **T** — temperature (°C)

5.3.7 **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 sub-section in this standard. Test procedures and severities, including initial and final I-V measurements in §10.

---

This is a Draft Document of the SEMI International Standards program. No material on this page is to be construed as an official or adopted Standard or Safety Guideline. Permission is granted to reproduce and/or distribute this document, in whole or in part, only within the scope of SEMI International Standards committee (document development) activity. All other reproduction and/or distribution without the prior written consent of SEMI is prohibited.
7 Apparatus

7.1 Sampling

7.1.1 Nine sample (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. Voc, Isc, etc.

7.2 Testing setup equipment

7.2.1 Visual Inspection, each 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 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 ±1°C.

7.2.3.5 Resistive loads sized such that at 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 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 ±1°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 ±2°C of that specified.

7.2.5.2.2 Relative humidity shall be controlled within ±5%RH of that specified.

7.3 Reference device (RD)

7.3.1 Reference device 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 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 are defined as Eq. (1) for test samples, and shall keep 90% at least in one month after a pre-test.

\[
\text{Relative Performance data loss(\%)} = \left( \frac{\text{Final} - \text{Initial}}{\text{Initial}} \right) \times 100\% \tag{1}
\]

8.2 Reference device

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 ±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.

9.2 RSD is defined as Eq. (2).

\[
RSD(\%) = \frac{\text{standard deviation}}{\text{average}} \times 100\%
\]

9.3 The non-uniformity is defined as Eq. (3), max and min is symbol of detector signal.

\[
\text{Non-uniformity}(\%) = \frac{\text{max} - \text{min}}{\text{max} + \text{min}} \times 100\%
\]

10 Testing Procedures

10.1 Test Sample: There are five groups of test samples fulfill the qualification test sequences in Figure 1. Each box refers to the corresponding sub-clause in this test method. Test procedures and severities defined in Chapter 10 include initial and final measurements where necessary. However, with regard to the tests of initial and final measurements, it should be noted that the procedures laid down in SEMI PV57, these tests shall be carried out within ± 5% of the specified irradiance and within ± 2°C of the specified temperature. Any single test, executed independently of a test sequence, shall proceed by the initial tests of Visual Inspection and I-V measurement. In carrying out the tests, the tester shall strictly observe the manufacturer's handling, mounting and connection instructions. Thin film technologies can have different stabilization characteristics. It is impossible to define a single stabilization procedure applicable to all thin-film technologies. This procedure tests the DUT and attempts to reach a stabilized condition before a final test.

10.2 Pass Criteria: Test sample design shall be judged to have passed the qualification tests, if each test sample meets all the following criteria:

10.2.1 After the final light soaking, the maximum power at STC or SRC is not less than 90% of the minimum value specified by the manufacturer in § 8.1.2;

10.2.2 No sample has exhibited any open-circuit during the tests, and connect each ample to the appropriate load by connecting the positive terminal of the sample to the positive terminal of the power supply and the second terminal accordingly;

10.2.3 There is no visual evidence of a major defect, as defined in § 10.3;

10.2.4 The specific requirements of the individual tests are met;

10.2.5 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 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.

10.3 Visual Inspection

10.3.1 Nine test samples for qualification testing (plus spares as desired) came from random from a production batch or batches, in accordance with the procedure given in IEC 60410. Test samples manufactured from specified materials and components in accordance with the relevant drawings and process sheets, and subjected to the manufacturer's normal inspection, quality control and production acceptance procedures.

10.3.2 For the purposes of design qualification, the following items are considered major defects.

10.3.3 Broken, cracked, or torn external surfaces, including superstrates, substrates and frames;
10.3.4 Bent or misaligned external surfaces, including superstrates, substrates and frames to the extent that the installation and/or operation of the module would be impaired;

10.3.5 Voids in, or visible corrosion of any layers of the active circuitry of test sample, extending over more than 10 % of any cell;

10.3.6 Bubbles or delamination forming a continuous path between any part of the electrical circuit and the edge of test sample;

10.3.7 When a test sample has a loss of mechanical integrity, the installation and/or operation would be impaired.

10.4 I-V Measurement: This defined in ¶ 7.2.2 and refer to SEMI PV57

10.5 Light Soaking

10.5.1 In order to anneal and stabilize the electrical characteristics of test sample by simulated solar irradiation approach from 10 min to 30 min, some requirements are written as follows.

10.5.2 Setting reference device, the irradiance (a) for outdoor application, between 600 W ⋅ m⁻² and 1000 W ⋅ m⁻², or (b) for low lighting application less than 300 W ⋅ m⁻², then record the irradiance. Test time refers to Table 1.

<table>
<thead>
<tr>
<th>Table 1 Level Type of Light Soaking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level type</strong></td>
</tr>
<tr>
<td>Pre-test time, hr</td>
</tr>
<tr>
<td>test time, hr</td>
</tr>
</tbody>
</table>

10.5.3 Attach the resistive or SMU loads to test sample and mount them. Subject each test sample to irradiation until its maximum power value stabilizes. Stabilization occurs when measurements from two consecutive periods of at least 43 kWh ⋅ m⁻² each integrated over periods when the temperature is between 40°C and 60°C, meet the following check criteria is defined as Eq. (4), having deviations 2% or less.

\[
\text{check criteria} = \left( \frac{\text{max} - \text{min}}{\text{average}} \right) \times 100\%
\]

10.5.4 Ensure temperature of test sample does not vary more than ±2°C within the range of 40°C to 60°C during the test, and record the temperature.

10.5.5 Final measurements: Repeat test visual Inspection and I-V measurement at STC or SRC. And results meet the following relative performance data loss (%) < 5% (see eq. (1)).

10.6 Thermal Cycle: To determine the ability of the DUT to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature.

10.6.1 Install the DUT(s) at room temperature in the chamber.

10.6.2 Connect the temperature monitoring equipment to the temperature sensor(s). The temperature sensors attach to the front or back surface of the DUT, near the middle. If more than one DUT tested simultaneously, it will suffice to monitor the temperature of one representative sample.

10.6.3 Close the chamber and, subject the DUT(s) to cycling between module temperatures of -10°C ± 2°C and +60°C ± 2°C. The rate of change of temperature between the low and high extremes shall not exceed 100 °C/h and the module temperature shall remain stable at each extreme for a period of at least 10 min. The cycle time shall not exceed 6 hr. The number of cycles shall be as shown in the relevant blocks in Figure 1 and Table 2.

10.6.4 Test cycle refer to Table 2.
<table>
<thead>
<tr>
<th>Level type</th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test cycle times</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>test cycle times</td>
<td>≥ 50</td>
<td>≥ 150</td>
</tr>
</tbody>
</table>

10.6.5 Throughout the test, record the DUT temperature and monitor the continuity of the DUTs.

10.6.6 Final measurements: Before a minimum recovery time of 1 hr, repeat test visual inspection and I-V measurement at STC or SRC. And results meet the following relative performance data loss (%) < 5% (see eq. (1)).

10.7 Damp Heat: To determine the ability of the DUT to withstand the effects of long-term penetration of humidity. The test shall be carried out in accordance with IEC 60068-2-78 with the following provisions.

10.7.1 Install the DUT(s) at room temperature in the chamber.

10.7.2 The following severities are applied. (a) test temperature: 65°C ± 2°C; (b) relative humidity: 65%RH ± 5%RH; (c) test duration refer to Table 3.

<table>
<thead>
<tr>
<th>Table 3 Level Type of Damp Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level type</td>
</tr>
<tr>
<td>Test time, hr</td>
</tr>
</tbody>
</table>

10.7.3 Final measurements: Before a minimum recovery time of 1 hr, repeat test visual inspection and I-V measurement. And results meet the following relative performance data loss (%) (see eq. (1)) criteria < 5%.

10.8 Combine Thermal Cycle and Damp Heat: To determine the ability of the DUT to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature, and the effects of long-term penetration of humidity.

10.8.1 Before install the DUT(s) at room temperature in the chamber of damp heat, shall be introduced into the chamber with thermal cycle preconditioning repeat change temperature by 50 cycle times.

10.8.2 The following severities are applied. (a) Test temperature: 65°C ± 2°C; (b) Relative humidity: 65%RH ± 5%RH; (c) Test duration refer to Table 3.

10.8.3 Final measurements: before a minimum recovery time of 1 hr, repeat test visual inspection and I-V measurement at STC or SRC. And results meet the following relative performance data loss (%) < 5% (see eq. (1)).

10.9 Data Analysis:

10.9.1 Provide calculation method of performance data ref to SEMI PV57 and SEMI PV69.

10.9.2 This clause describes a procedure for calibrating test sample in natural or simulated sunlight against a reference cell whose calibration is traceable to SI units. The spectral response match between the reference cell and test sample under the illumination used for the calibration shall be determined by the procedure given in IEC 60904-7. If the spectral mismatch correction is less than 1%, the mismatch correction may be omitted.

11 Reporting Results

11.1 The test report shall include, at minimum, the following:

11.1.1 A title.

11.1.2 Record the name and address of the test laboratory and location.

11.1.3 Unique identification of the certification or report and of each page.

11.1.4 Name and address of client, where appropriate.

11.1.5 Description and identification of the item tested.
11.1.6 Characterization and condition of the test item.
11.1.7 Date of receipt of test item and date(s) of test, where appropriate.
11.1.8 Identification of test method used.
11.1.9 Reference to sampling procedure, where relevant.
11.1.10 Any deviations from, additions to or exclusions from the test method, and any other information relevant to specific tests, such as environmental conditions.
11.1.11 Measurements, examinations and derived results supported by tables, graphs, sketches and photographs.
11.1.12 A statement of the estimated uncertainty of the test results (where relevant).
11.1.13 A signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue.
11.1.14 Where relevant, a statement to the effect that the results relate only to the items tested.
11.1.15 A statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory.

12 Related Documents

12.1 ASTM Standards
ASTM E927—Standard specification for solar simulation for terrestrial photovoltaic testing
ASTM E1021—Standard test method for spectral responsivity measurements of photovoltaic devices

12.2 ISO Standards
ISO 3534 - Statistics -- Vocabulary and symbols
ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories

12.3 Other Documents
Teng-Chun Wu, Shu-Tsung Hsu and Yean-San Long, PVSEC-23 (2013).
Teng-Chun Wu, Shu-Tsung Hsu and Yean-San Long, JEPE2014, 8, 6, 1059.
http://rredc.nrel.gov/solar/spectra/am1.5/
Principles of Instrumental Analysis, Douglas A. Skoog, F. James Holler and Stanley R. Crouch.
APPENDIX 1
REPORTING FORM (DEMO)

NOTICE: The material in this Appendix is an official part of SEMI [designation number] and was approved by full letter ballot procedures on [A&R approval date].

A1-1 Description of Testing Laboratory: Measurement of test data (e.g.SR) need be operated by the 3rd party lab, e.g., ISO 17025 accredited lab.

A1-1.1 Basic Information of Testing Laboratory

<table>
<thead>
<tr>
<th>Table A1-1 Basic Information of Testing Laboratory List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory ID/Name</td>
</tr>
<tr>
<td>Address</td>
</tr>
</tbody>
</table>

A1-1.2 Description of Testing Sample

<table>
<thead>
<tr>
<th>Table A1-2 Description of Testing Sample List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID</td>
</tr>
<tr>
<td>Sample Dimension</td>
</tr>
<tr>
<td>Sample Material</td>
</tr>
<tr>
<td>Packaged/Window Material</td>
</tr>
<tr>
<td>Temperature Sensor</td>
</tr>
<tr>
<td>UV-Cut</td>
</tr>
<tr>
<td>Sample Type</td>
</tr>
<tr>
<td>Level Type</td>
</tr>
</tbody>
</table>

A1-1.3 Testing Data

A1-1.3.1 All data measured in each sweep direction (forward or backward) need test at least five times. The average data and standard deviation are listed in the following table.

<table>
<thead>
<tr>
<th>Table A1-3 Visual Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample #</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Supplementary information: N/A
### Table A1-4 Maximum Power Determination

<table>
<thead>
<tr>
<th>Module temperature [°C]</th>
<th>Radiant source</th>
<th>Solar simulator</th>
<th>Irradiance [W·m⁻²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample#</td>
<td>Test Date</td>
<td>Vₜₜ [V]</td>
<td>Iₛₛ [A]</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>--------</td>
<td>--------</td>
</tr>
</tbody>
</table>

Supplementary information:

1. The results were not corrected by spectral mismatch factor.
2. The results were preconditioning before measurement max. power determination.

### Table A1-5 Thermal Cycling Test

<table>
<thead>
<tr>
<th>Sample#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Date</td>
</tr>
<tr>
<td>Start</td>
</tr>
<tr>
<td>--------</td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-5-1 Visual Inspection (after Thermal Cycling Test)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Test Date</th>
<th>Nature and position of initial findings – comments or attach photos</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------</td>
<td>----------</td>
<td>------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-5-2 Maximum Power Determination (after Thermal Cycling Test)

<table>
<thead>
<tr>
<th>Radiant source</th>
<th>Solar simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module temperature [°C]</td>
<td></td>
</tr>
<tr>
<td>Irradiance [W·m⁻²]</td>
<td></td>
</tr>
<tr>
<td>Sample#</td>
<td>Test Date</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
</tbody>
</table>

Supplementary information:

1. The results were not corrected by spectral mismatch factor.
2. The results were not preconditioning before measurement max. power determination.
### Table A1-6 Damp Heat Test

<table>
<thead>
<tr>
<th>Sample#</th>
<th>Test Date</th>
<th>Total Time (hours)</th>
<th>Open circuits (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td>End</td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-6-1 Visual Inspection (after Damp Heat Test)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Test Date</th>
<th>Nature and position of initial findings – comments or attach photos</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-6-2 Maximum Power Determination (after Damp Heat Test)

<table>
<thead>
<tr>
<th>Radiant source</th>
<th>Solar simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module temperature [°C]</td>
<td></td>
</tr>
<tr>
<td>Irradiance [W·m⁻²]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample#</th>
<th>Test Date</th>
<th>Vₜₐₜ [V]</th>
<th>Iₜₐₜ [A]</th>
<th>Vᵢₘₚ [V]</th>
<th>Iᵢₘₚ [A]</th>
<th>Pᵢₘₚ [W]</th>
<th>FF [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information:

[1] The results were not corrected by spectral mismatch factor.
[2] The results were not preconditioning before measurement max. power determination.

### Table A1-7 Control Group

<table>
<thead>
<tr>
<th>Sample#</th>
<th>Test Date</th>
<th>Total Time (hours)</th>
<th>Open circuits (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td>End</td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-7-1 Visual Inspection (after all tests)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Test Date</th>
<th>Nature and position of initial findings – comments or attach photos</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information: N/A

### Table A1-7-2 Maximum Power Determination (after all tests)

<table>
<thead>
<tr>
<th>Radiant source</th>
<th>Solar simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module temperature [°C]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample#</th>
<th>Test Date</th>
<th>Vₜₐₜ [V]</th>
<th>Iₜₐₜ [A]</th>
<th>Vᵢₘₚ [V]</th>
<th>Iᵢₘₚ [A]</th>
<th>Pᵢₘₚ [W]</th>
<th>FF [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supplementary information:
A1-1.4 Others Descriptions

A1-1.4.1 Measured Methods
A1-1.4.1.1 The testing items and methods listed in this report have been approved by the commissioners and commissioned parties and then been adopted for the calibration.
A1-1.4.1.2 The measured procedure was carried out according to.

A1-1.4.2 Standard Equipment of System

<table>
<thead>
<tr>
<th>Item</th>
<th>Traceability Org.</th>
<th>Report No.</th>
<th>Traceability Date</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary reference cell</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature monitor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference detector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A1-1.4.3 Environmental Conditions
A1-1.4.3.1 The calibration was performed under the following environmental conditions.
A1-1.4.3.2 Ambient temperature: (±) °C
A1-1.4.3.3 Relative humidity: (±) %RH
A1-1.4.4 Relative expanded combined uncertainty
A1-1.4.4.1 Relative expanded combined uncertainty was performed according to.
A1-1.4.4.2 The relative expanded uncertainty, with a coverage factor k = 2 and a confidence level of about 95 %.
A1-1.5 Appendix
A1-1.5.1 Photos of testing sample

<table>
<thead>
<tr>
<th>Item</th>
<th>Front-side</th>
<th>Back-side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTICE: SEMI makes no warranties or representations as to the suitability of the Standards and Safety Guidelines set forth herein for any particular application. The determination of the suitability of the Standard or Safety Guideline is solely the responsibility of the user. Users are cautioned to refer to manufacturer’s instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. Standards and Safety Guidelines are subject to change without notice.

By publication of this Standard or Safety Guideline, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any items mentioned in this Standard or Safety Guideline. Users of this Standard or Safety Guideline are expressly advised that determination of any such patent rights or copyrights and the risk of infringement of such rights are entirely their own responsibility.