Background Statement for SEMI Draft Document 6071
NEW STANDARD: TEST METHOD FOR POLYMER FOIL DEPENDENT DISCOLORATION OF SILVER FINGERS ON PV MODULES

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:
With the increasing capacity of PV installation, reliability of photovoltaic (PV) module becomes an important issue during the long term application. According to the recent reports, a discoloration of silver fingers in the PV modules were observed in many systems less than 5 year. The root cause of finger discoloration has been widely discussed and also proposed in the literatures. To approach the susceptibility or resistivity to the occurrence of discoloration, it is necessary to develop a method that could induce the finger discolored by testing condition.
This standard is going to deliver an accelerated test method for finger discoloration by Pressure Cooker Tests (PCT). Mini modules are tested and further analyzed for the relevant color change of silver finger metallization. Typically, it is efficient to evaluate the moisture resistance of packaged solid state devices using moisture condensing or moisture saturated steam environments. Nevertheless, there is no standard PCT condition for PV polymer foil been proposed, which may cause unreasonable requirement or aging result. This standard is going to develop an accelerated test method for mini modules influenced by temperature and humidity. The standard contains two parts to evaluate thermo-humidity susceptibility of PV module. The first part reveals the preparation of PV mini module and testing condition of PCT. The second part is to deliver the measuring methodology by color quantification of silver fingers.

Review and Adjudication Information

	Task Force Review	**Committee Adjudication**
Group:	PV Reliability Test Method Task Force	Taiwan PV Technical Committee
Date:	October 13, 2017	October 18, 2017
Time & Time zone:	TBD	14:00 – 16:00 / Taiwan (GMT+8)
Location:	ITRI	Nankang Exhibition Center
City, State/Country:	Hsinchu, Taiwan	Taipei, Taiwan
Leader(s):	Hung-Sen Wu (ITRI), Jay Lin (PV guider)	B.N. Chuang (ITRI), JS Chen (Tera Solar) Ray Sung (UL Taiwan)
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This meeting's details are subject to change, and additional review sessions may be scheduled if necessary. Contact the task force leaders or 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.

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LETTER BALLOT

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LETTER BALLOT

SEMI Draft Document 6071
NEW STANDARD: TEST METHOD FOR POLYMER FOIL DEPENDENT DISCOLORATION OF SILVER FINGERS ON PV MODULES

1 Purpose

1.1 The purpose of this standard is to standardize the accelerated evaluation method for discoloration of silver fingers on photovoltaic (PV) modules. The test is performed with designed mini module in a pressure cooker with moisture condensing or moisture saturated steam environment.

1.2 PCT (pressure cooker test) is a highly accelerated test which employs high pressure, humidity and temperature under condensing conditions to accelerate moisture penetration into laminated mini modules.

1.3 The PV polymer foil suppliers, PV module manufactures and buyers, or any other party interested, can thus have common standards to test and select PV encapsulation materials for PV modules efficiently.

2 Scope

2.1 This test is used to evaluate the susceptibility and occurrence of discoloration of PV finger metallization. The influence of encapsulation materials used in PV modules such as Ethylene-vinyl acetate (EVA), back sheet polymer foil or any other materials that protect crystalline Si cells in PV modules can be tested with this method.

2.2 Some cautions should be considered when performing this test and evaluating test results. Failure mechanisms, both internal (e.g., due to embrittlement of PET) and external (e.g. moisture ingress from non-sealed edge), may be produced which are not applicable to the intended application use conditions.

2.3 This standard defines the specific testing methods, testing conditions and evaluation method for PV polymer foils.

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 predict the lifetime of PV modules.

3.2 This standard is not to completely simulate extended Damp Heat test.

4 Referenced Standards and Documents

4.1 IEC 61215 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval IEC Standards.

4.2 JESD22-A102-C, "Accelerated Moisture Resistance - Unbiased Autoclave", Dec. 2000.

4.3 SEMI PV72-0316 —Test method to evaluate an accelerated thermo humidity resistance of PV encapsulation.

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *RH – Relative Humidity (%)*

5.1.2 *Photovoltaic - PV*

5.1.3 *c-Si - Crystalline Silicon*

5.1.4 *Ethylene-vinyl acetate - EVA*

5.1.5 *PCT - Pressure Cooker Test*

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6 Sample Preparation

The sample is prepared by the conventional solar module lamination process, which is the sandwich of glass/encapsulant/solar cell/encapsulant/polymer foil (back sheet). Figures 1 and 2 show the cross-sectional image and the overview of a single-cell-laminate. For each test with different encapsulation materials, 3 samples are suggested to be prepared, in which one is reference sample and another one is testing sample.

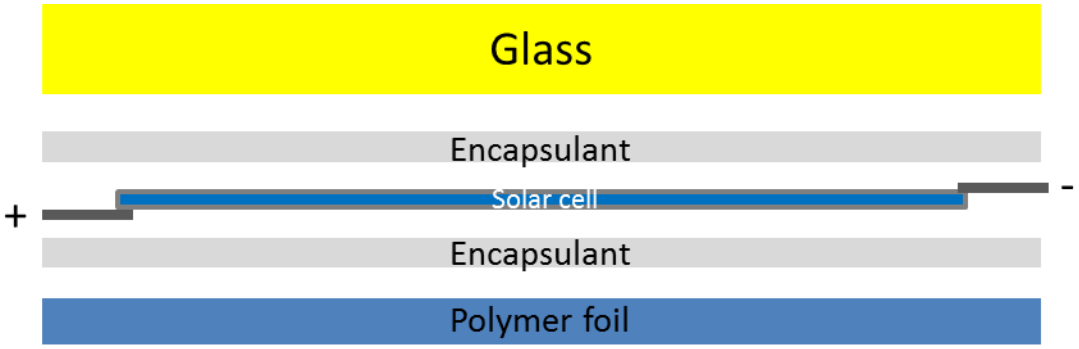


Figure 1 Section view of a mini module

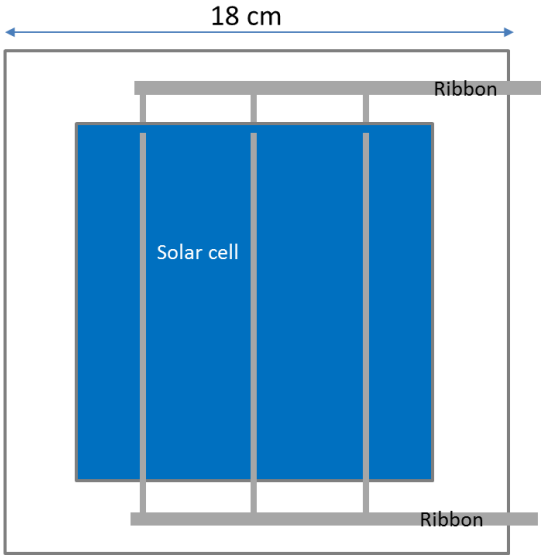


Figure 2 Schematic of a laminated mini module

7 Procedure

The measured performance result of PCT for PV modules is highly responsive to the encapsulation method of mini modules. A reasonable evaluation result requires the same encapsulation scheme that has been shown in section 6. The details of the color quantification after PCT should be clearly described in the report. Fig. 3 shows the testing procedures for the PCT test.

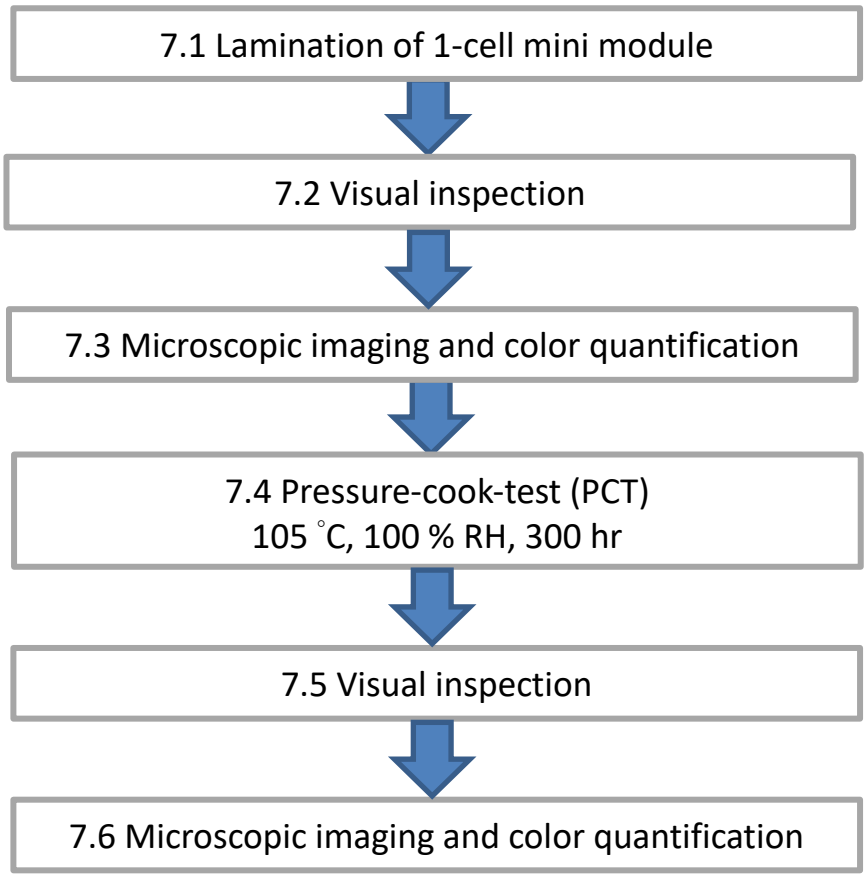


Figure 3 Testing Procedures

7.1 Lamination of 1-cell mini module

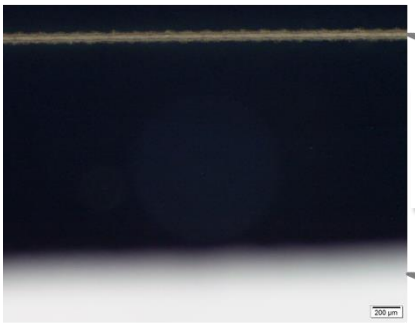
To laminate the module in order of glass/encapsulant/solar cell/encapsulant/polymer foil (back sheet).

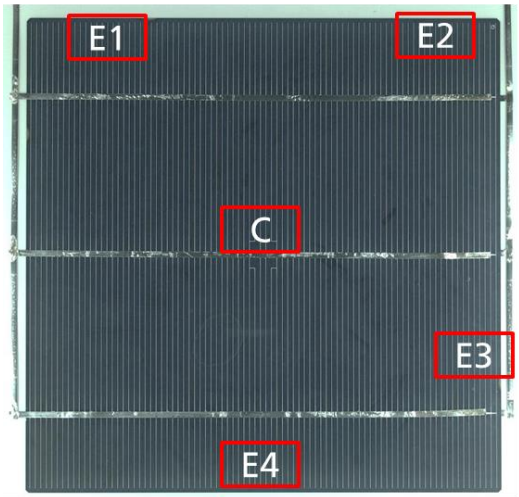
7.2 Visual inspection

Check and document (photo) the overall status of the mini module: back sheet, glass, contacts, delamination

7.3 Microscopic imaging and color qualification

The rationale behind the analysis is the finding that the discoloration known as snail trails occurs at cell edges or cell cracks where water can reach the cell surface due to diffusion. In the test suggested here, no intentional cracks are needed. Instead, just the edges of the one-cell-module are inspected carefully. Therefore, the following procedure describes the microscopic analysis of grid finger discoloration at the cell edges compared to a position at the center of the cell which should remain unaffected throughout the testing period. Optical observations such as microscope or electroluminescence is suggested if needed. At least four positions at the cell edges and three in the center of the cell have to be scanned. Note that the selected center position of the cell should be as much as clean, flux-free, and unoxidized. A color value of the grid fingers has to be measured at each position using appropriate software for example “Image J”. The result should be given as CMYK values [%]. If the software gives RGB values instead, the data should be converted by using available color space tables or calculation tools. Most important, a white reference material (e.g. a white sheet of paper) has to be analyzed in parallel to each microscopic imaging. The sample data are than normalized to the measured white standard compared with perfect white color {C(0), M(0), Y(0), K(0)}. Subsequently, the normalized single values are used to calculate the delta between initial and after PCT status. Finally, from each “edge” value the “center” value is subtracted. For the evaluation of a brownish discoloration the M and Y values are the most important. Therefore, the sum of M and Y values from all edge positions are averaged. This number is then used as a measure for the increase of grid finger discoloration. Below, an example is shown to illustrate the whole procedure.





Step B

Position	Status	normalized CMYK C	M	Y	K	Δ CMYK C	M	Y	K
C	initial	0%	4%	16%	45%				
E1		0%	7%	18%	44%				
E2		0%	6%	17%	44%				
E3		0%	5%	18%	43%				
E4		0%	7%	16%	45%				
C (average)	after PCT	0%	5%	17%	45%	0%	1%	1%	0%
E1		0%	8%	21%	43%	0%	1%	3%	-1%
E2		0%	9%	26%	41%	0%	3%	9%	-3%
E3		0%	9%	24%	42%	0%	4%	6%	-1%
E4		0%	7%	21%	43%	0%	0%	5%	-2%
E1	edge vs. center					0%	0%	2%	-1%
E2						0%	2%	8%	-3%
E3						0%	3%	5%	-1%
E4						0%	-1%	4%	-2%
mean value edges						0%	1%	5%	-2%

grid finger color value M+Y 6%

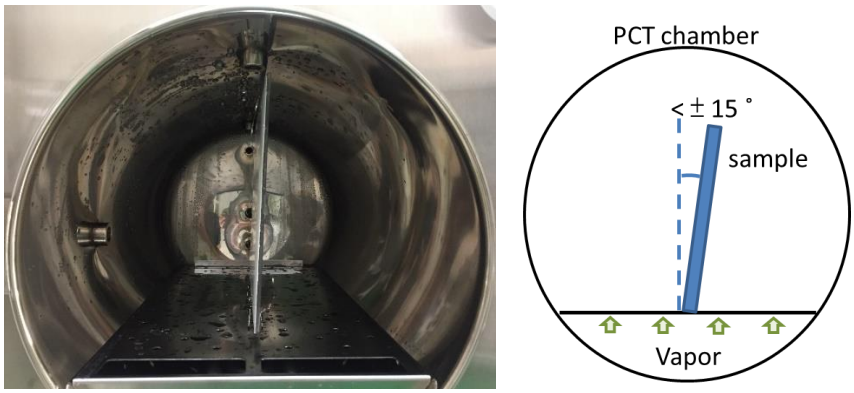
7.4 PCT test

7.4.1 The test condition is listed in Table 1.

Table 1 PCT test condition

Temperature (°C)	Relative Humidity (%)	Vapor pressure(psi/kPa)
105 ± 2	100 %	9.7 ±2 / 205± 13.8

7.4.2 Figure 4 illustrates the test sample in a pressure cooker chamber. The test sample should be placed in the center of the chamber to approach the well uniformity of the temperature and humidity, as shown in Fig 4 (a). And Fig. 4 (b) illustrates the arrangement of the test sample and its relative position. Note that samples in a PCT chamber should be as much as parallel to vapor direction, in which the inclination angle should be less than ±15 ˚ to refrain from the accumulated moisture depositing on the sample surface. And the samples space should be more than 3 cm.



(a) (b)

Figure 4 (a) Test sample in the PCT chamber (b) Sample position and inclination.

7.4.3 Test duration is set to be 300 hours, which is sufficient to tell the difference among common PV polymer foils. Extended test duration is available for special purpose or materials.

7.5 Visual inspection:

To inspect the defects in mini-module, see 7.2.

7.6 Microscopic imaging and color quantification, see 7.2

8 Apparatus

8.1 Reliability tests

8.1.1 Pressure Cooker Apparatus – a testing chamber which is used to age the sample of interest

a) A pressure cooker with automatic temperature and humidity control, capable of subjecting one or more samples to the test condition specified in Table 1.

b) Means for mounting or supporting the module(s) in the chamber, so as 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 module(s) is (are) thermally isolated.

c) Means for measuring and recording the module temperature to an accuracy of ± 1 °C. (It is sufficient to monitor the temperature of one representative sample, if more than one sample is being tested.)

8.2 Analytical tools for post-treatment

8.2.1 Light microscope — a device which is used to check color of silver fingers in microscopic detail.

a) The magnification should be at least (50 ~ 100) fold and the image resolution should be 72 dpi or better

8.2.2 Degree of discoloration — a software which is able to quantify the image colors within a region of interest (ROI; i.e. grid fingers). The result should be given as RGB or CMYK values.

9 Report

The following details shall be specified in the applicable procurement document:

(a) Test duration.

(b)Yellow and magenta values before and after treatment.

(c) Microscopic images of grid finger positions at the center and at the edges of test sample before and after treatment.

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Reference

[1] Meyer, S.; Timmel, S.; Gläser, M.; Braun, U.; Wachtendorf, V.; Hagendorf, C., Polymer foil additives trigger the formation of snail trails in photovoltaic modules, Solar Energy Materials & Solar Cells 130 (2014) 64–70.

[2] Meyer, S.; Timmel, S.; Richter, S.; Werner, M.; Gläser, M.; Swatek, S.; Braun, U.; Hagendorf, C., Silver nanoparticles cause snail trails in photovoltaic modules, Solar Energy Materials & Solar Cells 121(2014)171–175.

[3] Lee, Y.-H., Hsieh, H.-H., Wang, E.-Y., Chen, S.-H., Wu, H.-S., Wu, T.-C., Timmel, S., Richter, S., Meyer, S., Accelerated material testing to avoid grid finger discoloration, submitted for publication (2017).

APPENDIX 1REPORTING 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 need be operated by 3rd party testing lab, e.g., ISO 17025 accredited lab.

Basic Information of Testing Laboratory	
Laboratory ID/Name	
Address	

A1-1.1 Description of Testing Sample

Sample #	
Sample Group ID	
Model no.	
Sample S/N	

A1-1.2 Description of test procedure

Group ID _____ : PCT-10.1-Color change

A1-1.3 List of test results

	Initial examination	All modules
Color change	Discoloration	See table Color change Initial

Group A	1 Module	Sample Group ID A
PCT	Pressure Cooker test	See table PCT

	Final examination	All modules
10.1	Visual inspection	See table 10.1 Final
Color change	Discoloration	See table Color change Final

A1-1.4 Data of test results

Color change	**TABLE: Discoloration Initial**		
Test Date			
Sample#	Yellow [%]	Magenta [%]	Total [%]
Supplementary information: N/A			

PCT	**TABLE: Pressure Cooker test**	
Sample #		
Test Date [start/end]		
Duration test [hours]		
Test condition	Temperature [℃]	
	Relative humidity [%]	
	Pressure [Pa]	
Supplementary information: N/A		

10.1 Final	**TABLE: Visual inspection**	
Test Date		
Sample #	Test date	Nature and position of initial findings – comments or attach photos
Supplementary information: N/A		

Color change	**TABLE: Discoloration Final**		
Test Date			
Sample#	Yellow [%]	Magenta [%]	Total [%]
Supplementary information: N/A			

A1-1.5 Descriptions

A1-1.5.1 Date and Location of Test

The test was performed at ITRI and Fraunhofer CSP during the period from July 2016 to March 2017.

A1-1.5.2 Test Methods

2.1 The test items and test methods listed in this report have been approved by the commissioners and commissioned parties and then been adopted for the test.

2.2 All tests were carried out according to SEMI 6071: Test method for polymer foil dependent discoloration of silver fingers on PV modules.

A1-1.5.3 Equipment of test

Standard equipment	Serial No.	Traceability Unit	Report No.	Traceability Date	Due Date
PCT Chamber					
Light microscopy					
Color					

A1-1.6 References

6.1. SEMI 6071, Accelerated Moisture Resistance - Unbiased Autoclave.

A1-1.7 Appendices

1. Photos of mini-module

Figure 1 Front side

Figure 2 Rear side