

SEMI PV75-0823

TEST METHOD ON CELL LEVEL FOR POTENTIAL-INDUCED DEGRADATION SUSCEPTIBILITY OF SOLAR CELLS AND MODULE ENCAPSULATION MATERIALS

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1 Purpose

1.1 Potential-induced degradation (PID) is a serious reliability problem in PV power plants.

1.2 PID prone solar panels (modules) can suffer power loss within months or years of operation depending on environmental and installation conditions.

1.3 In particular, modules with silicon solar cells suffer from short circuiting (shunting), called potential-induced degradation of the shunting type (PID-s).

1.4 A technical specification for PID tests at standardized conditions for testing of PID susceptibility of commercial silicon solar modules is available (IEC TS 62804-1). PID tests on module level are effective as quality tests of final modules, but they are costly (require module manufacturing as well as large climate chambers for PID testing).

1.5 In order to ensure quality with respect to PID-s immunity, less expensive PID tests of upstream products such as solar cells and encapsulation materials are most desirable.

1.6 The purpose of this Test Method is the standardization of experimental setup and procedures for PID tests on solar cell level based on non-encapsulated silicon solar cells instead of complete modules. For PID-s sensitivity test on solar cells, an alternative test method is proposed to reduce the test period.

2 Scope

2.1 This Test Method defines procedures to test and evaluate the PID susceptibility of wafer-based silicon solar cells and module construction components.

2.2 The only type of PID that is considered within this Test Method is the shunting of silicon solar cells due to high voltage stress induced leakage currents. This type of PID is called PID-s.

NOTE 1: Different types of PID are the dissolution of antireflective layers, degradation of surface passivation or the degradation of metal contacts for crystalline silicon solar cells and the corrosion of transparent conductive oxide layers in thin film modules.

2.3 The Test Method is designed for silicon solar cells, having a front side emitter, a front side dielectric antireflective layer and front side contacts on top. For the sake of practicability and in order to minimize any border effects, solar cells tested with this Test Method must have edge lengths larger than 6 cm.

2.4 This Test Method is based on the fact that considered solar module designs comprise following layer stack (from top/sunny side to bottom): glass (or transparent polymer) cover sheet, polymeric encapsulation material, and solar cells. The materials of the solar module back-side and their stacking order do not impact the measurement results.

2.5 Depending on which component is altered/exchanged for sampling, solar cells, polymeric encapsulation foils, and glass sheets can be tested for their PID-s sensitivity. Following distinction is used in this Test Method:

1. PID test of solar cells.

2. PID test of encapsulation polymer sheets.
3. PID test of module (glass) cover materials.

2.6 With this Test Method, two or more different PID test specimens (hereafter: test specimens) can be compared quantitatively with respect to their PID-s sensitivity.

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3 Limitations

3.1 With this Test Method an absolute measure about the PID-s sensitivity of a specific material cannot be derived since the overall PID-s sensitivity depends on used PID auxiliary samples (refer to § 8.1).

4 Referenced Standards and Documents

4.1 IEC® Standards¹

IEC TS 62804-1:2015 — Photovoltaic (PV) Modules – Test Methods for the Detection of Potential-Induced Degradation – Part 1: Crystalline Silicon

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

5 Terminology

5.1 Abbreviations and Acronyms

- 5.1.1 *PID* — potential-induced degradation
- 5.1.2 *PID-s* — potential-induced degradation of the shunting type

5.2 Definitions

5.2.1 *PID auxiliary sample* — additional PID sensitive sample that is needed for probing of the specific PID test specimen.

5.2.2 *PID sensitivity* — qualitative and relative characteristic of solar cells that is used to describe how fast and how strong PID-s occurs under high voltage stress or qualitative and relative characteristic of encapsulation components (glass, polymer foils) that is used to describe their ability to promote PID-s when combined in solar modules with PID-s sensitive solar cells.

5.2.3 *PID test specimen* — a sample whose PID sensitivity is to be probed in a specific PID test experiment.

5.2.4 *potential-induced degradation* — change of physical properties of solar modules under high electrical potential drop between surfaces and encapsulated solar cells with (potentially) detrimental effect on the power output.

6 Summary of Test Method

6.1 General Remarks

6.1.1 IEC TS 62804-1 describes two different PID test methods for industrial scale solar modules. In the current Test Method, the second method of IEC TS 62804-1 (stress method b), contacting the surfaces with a conductive electrode¹) is adopted for a PID test using individual solar cells.

6.1.2 This Standard describes two test methods for PID-s sensitivity evaluation: basic test method (Method A) and alternative test method (Method B).

6.1.2.1 *Method A* — Like in module-based PID tests, solar cells, polymer encapsulation foils and cover glass sheets can be tested with respect to their PID sensitivity.

6.1.2.2 *Method B* — For the alternative test method, sodium is introduced to accelerate the testing process.

¹ International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.919.02.11, <http://www.iec.ch>. IEC trademark is owned by International Electrotechnical Commission.

NOTE 2: Method B is only applicable to PID test of solar cells.

6.2 Summary of Test Procedure

6.2.1 The sample stack, consisting of solar cell, polymer sheet and glass sheet, imitates the front side of a common solar module on an area smaller than a solar cell.

6.2.2 For Method A, the PID sensitivity of one of the three components can be tested when the other two components are PID sensitive. While Method B is limited to test the PID sensitivity of solar cells.

6.2.3 The sample stack is placed between a top electrode and base plate of the test setup and is subjected to an elevated temperature. Figure 1 shows the basic setup. In Method B, the polymer sheet will be replaced by the pretreated sodium-enriched hybrid polymer fabric, while the position of other materials remains as shown in Figure 1. Optionally, an electrically conductive rubber sheet can be placed between the glass sheet and top electrode to enhance the electrical contact uniformity. During the PID test period, a high positive voltage is applied to terminal H with respect to grounded base plate (terminal G).

6.2.4 The progress of PID-s is determined by measuring the shunt resistance (parallel resistance) of the solar cell.

6.2.4.1 This is done either during the PID test through a resistance measurement between terminals F and G, contacting the front side (grid finger or busbar), and back side contact respectively (in situ).

6.2.4.2 Alternatively, the shunt resistance can be measured before and after the PID test (ex situ), respectively.

6.2.5 An evaluation of the shunt resistance behavior yields a quantitative result for the relative PID sensitivity of different test specimens.

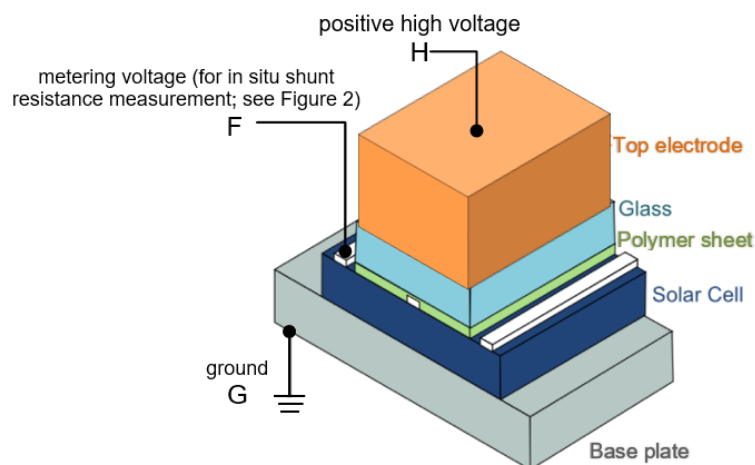


Figure 1
Sketch of the PID Sample Layer Stack and Electrical Contacts

7 Apparatus

7.1 The apparatus/setup used for this Test Method has to be able to apply a voltage (constant over time and laterally homogenous) across an imitated solar module layer stack, consisting of glass cover and encapsulant polymer on top of a solar cell (refer to Figure 1) at a defined temperature. The list below defines necessary devices and equipment. The corresponding wiring scheme is shown in Figure 2.

7.1.1 DC voltage source, capable of applying the maximum test voltage (e.g., maximum system voltage of the regarded module design) with positive polarity at the top electrode with a voltage tolerance of 1%.

7.1.2 Grounded base electrode, capable of contacting the solar cell.

7.1.3 Top electrode, capable of contacting the glass surface without any gap, with a size between $4\text{ cm}^2 \times 4\text{ cm}^2$ and full solar cell area, preferably of square dimension.

NOTE 3: For Test Method A (refer to ¶ 7.1.7.1) the electrode footprint should be smaller than the solar cell to be tested due to the front contacting of the solar cell for in-situ shunt resistance measurement.

7.1.4 Equipment for applying a constant force between top and base electrode (pressure >1 kPa).

7.1.5 Provisions for avoiding illumination of the solar cell under test.

7.1.6 Heat source, capable of heating the solar cell and the overlying layer stack to a constant temperature level, with an accuracy of better than $\pm 2^{\circ}\text{C}$; temperature sensor and controller with temperature indicator.

7.1.7 Equipment for shunt resistance measurement of solar cell with an accuracy of better than $\pm 1\%$ for resistance values below 1000 Ohm (either Method A or Method B):

7.1.7.1 *Method A* — In situ measurement and record of solar cell shunt resistance during PID test via contacts to the active layers (ohm-meter in Figure 2). Optional: measurement of additional electrical solar cell parameters (e.g., dark I-V curve).

7.1.7.2 *Method B* — Ex situ measurement of solar cell shunt resistance before and after the PID test, respectively. Optional: measurement of additional electrical solar cell parameters (e.g., V_{oc} , I_{sc} , P_{mpp} , I-V curve, dark I-V curve).

7.1.8 *Optional* — An appropriate device for resolving and monitoring the leakage current from the top electrode to the grounded base plate (ampere-meter in Figure 2).

7.1.9 For Method B, an external heat source, capable of heating the sodium chloride solution soaked hybrid polymer fabric to a constant temperature level, with an accuracy of better than $\pm 2^{\circ}\text{C}$, is required. It has to be able to provide the heating temperature constant over time and laterally homogenous.

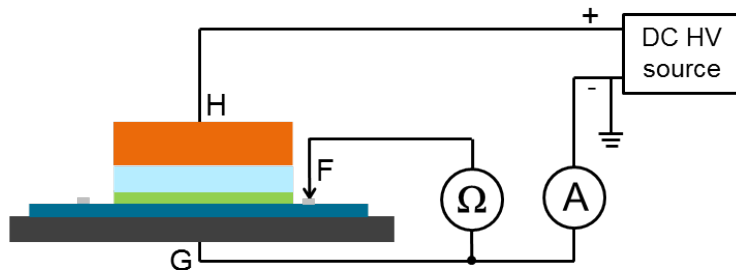


Figure 2
Example Wiring Scheme Including Optional In Situ Shunt Resistance and Leakage Current Measurement

8 Reagents and Materials

8.1 PID Auxiliary Samples/Consumables — Method A

8.1.1 This Test Method is based on the imitation of a solar module front layer stack on a small-scale area on top of a silicon solar cell. The three test scenarios that are described in § 2, each require PID auxiliary samples (hereafter: auxiliary samples) with constant PID-s sensitivity.

1. PID testing of solar cells requires PID sensitive polymer sheets and glass sheets as auxiliary samples.
2. PID testing of polymer sheets requires PID sensitive solar cells and glass sheets as auxiliary samples.
3. PID testing of glass sheets requires PID sensitive solar cells and polymer sheets as auxiliary samples.

8.1.2 Auxiliary samples need to be out of the same production batch for each experiment series, respectively. Their material parameters shall be spatially and temporally constant.

8.1.3 The choice of definitive materials (type, manufacturer) is not specified for reasons of worldwide and long-term availability that cannot be guaranteed for PV materials (polymer, glass sheets) or special solar cells since they are consumed during PID tests.