

SEMI PV93-0320

TEST METHOD FOR ACCELERATED CELL LEVEL TESTING FOR LIGHT AND ELEVATED TEMPERATURE INDUCED DEGRADATION (LeTID) SUSCEPTIBILITY OF SOLAR CELLS

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1 Purpose

- 1.1 The purpose of the test method is to standardize the procedures, analysis and reporting for quantitatively determining light and elevated temperature induced degradation (LeTID) susceptibility of silicon solar cells.
- 1.2 The standard is necessary since the LeTID effect is highly sensitive to temperature and charge carrier injection of solar cells under illumination or current injection.
- 1.3 The test method covers the procedure for gauging silicon based photovoltaic (PV) cells with respect to LeTID with the aim of comparison/benchmarking of different solar cell concepts, production processes as well as silicon materials.
- 1.4 The test method defines consistent parameters for testing LeTID susceptibility of solar cells, since the LeTID effect depends on the working point of the solar cell under test, that is, if the solar cell is tested at short circuit current (I_{sc}), open circuit voltage (V_{oc}) or maximum power point (P_{mpp}).
- 1.5 The test method gives as a result a metric for the strength of LeTID susceptibility and for assessing LeTID mitigation procedures. It may be implemented in statistical process control routines in production on a small sample basis.
- 1.6 The test method is targeted at fast quantitative predictions of LeTID for solar cells later on integrated in PV modules. It is not intended for a quantitative prediction of the performance of the modules in the field.

2 Scope

- 2.1 The test method is intended for LeTID testing of crystalline silicon based solar cells and test devices (e.g., mini modules).
- 2.2 LeTID types which can be traced back to be caused by charge carrier injection in the PV cell are considered within the scope of this test method.

NOTE 1: Other types of LID which are traced back to various module components, that is, delamination, discoloring or other physical parameters beside carrier injection, that is, SiN UV (i.e., anti-reflection coating) degradation are not included within this Standard.

- 2.3 Suggestions for technological data interpretation are included in later sections of this Test Method. However, the obtained results are beyond the normative scope of this standard. Any of such interpretations should be agreed upon between interested parties prior to testing. Since the method is suitable and intended for statistical process control on a small sample basis, it is possible and recommended to analyze the statistics of accumulated data from time to time to identify further improvement potentials which are not visible in individual measurements.

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 LeTID in PERC solar cells is essentially driven by temperature and the charge carrier injection level. Thus, the precision of the obtained results are limited through interference with other types of LID/CID occurring beyond the specified test setup and parameters.

4 Referenced Standards and Documents

4.1 IEC Standards¹

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

IEC 60904-9 — 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 *LeTID* — light and elevated temperature induced degradation

5.1.2 *LID* — light induced degradation

5.2 Definitions

5.2.1 *light and elevated temperature induced degradation (LeTID)* — change of physical properties of solar cell or modules under illumination and at elevated temperature with effect on the power output.

5.2.2 *light induced degradation (LID)* — change of physical properties of solar cell or modules under illumination with effect on the power output.

6 Summary of Test Method

6.1 The test method applies an electrical current equivalent to a charge carrier injection of 1 sun or an illumination of 1 sun at an elevated solar cell temperature of 75°C to 130°C to drive the LeTID effect and thus degrade the cell in a well-controlled and accelerated manner. It is assumed that an electrical current to the forward-biased cell is equivalent to excess charge carriers generated by exposure to sun light. A corresponding generic hardware setup is described in Figure 1 below.

6.2 Initially the solar cell has to be electrically characterized and conditioned in order to distinguish and quantitatively assess the LeTID susceptibility from different types of LID (e.g., boron-oxygen, iron-boron).

6.3 LeTID of solar cells depends on material and production processes and passes through three phases: degradation, plateau, and regeneration possibly until the initial cell parameters are reached. Please note that each phase may vary strongly in duration (see Figure 1).

6.4 LeTID susceptibility with regard to degradation, plateau and regeneration phases is monitored through measurements of the solar cell performance parameters V_{oc} , I_{sc} , V_{mpp} , I_{mpp} .

6.4.1 Below 50°C LeTID is not significant, hence the solar cell can be removed from the degradation setup to the solar cell testing setup (flasher), without ongoing degradation. However, the solar cell under test must be stored in dark place at room temperature (RT).

6.4.2 An illumination device may serve for ‘in situ’ measurements of cell performance parameters at regular intervals at the LeTID degradation temperature.

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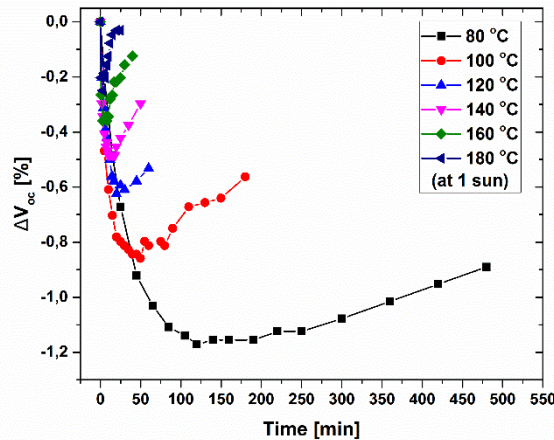


Figure 1
LeTID Degradation of the Voc Under Various Degradation Temperatures
of Similar Processes PERC Cells

6.5 Two test modes are defined:

6.5.1 *Working Mode 1 (normative)* — Mandatory test conditions for LeTID with defined temperature and defined illumination or equivalent current for charge carrier injection. Quantitative results for LeTID cell parameter degradation are measured under standard conditions.

6.5.2 *Working Mode 2 (explorative)* — Optional test conditions are specified for research and development purposes. This method applies, if the degradation mechanism is not clear or if a semi-quantitative assessment of materials, solar cell designs or productions processes is required.

7 Apparatus

7.1 *Overview* — The essential principle of the test method is that LeTID is caused by excess minority charge carriers rather than a direct interaction between light and material. Thus, the apparatus has to provide a charge carrier current injection under forward bias at $I = I_{sc} - I_{mpp}$ which is in the order of magnitude of ≤ 1 A for a standard $156.75 \text{ mm} \times 156.75 \text{ mm}$ solar cell. This is comparable to the level of excess minority charge carriers under outdoor conditions of 1 sun illumination at maximum power point (MPP). Alternatively, the apparatus may provide a charge carrier injection through a homogeneous illumination of $1 [\text{sun}] \times (I_{sc} - I_{mpp}) / I_{sc}$ with the solar cell being under V_{oc} conditions. For thermal activation the LeTID process is accelerated by raising the temperature to 75°C in working mode 1 and up to 130°C in working mode 2.

7.2 *Hardware General Considerations* — Hardware for the following functions shall be implemented (see Figure 2):

7.2.1 A device with electrical connectors to allow for injecting a current at a level of $I = I_{sc} - I_{mpp}$ in constant current mode for any solar cell (A) or a lateral homogeneous illumination of 1 sun (B). For keeping the solar cells at the desired temperature a temperature controlled chuck shall be used. The correctness of the temperature control is of high importance and the tolerance of the temperature is $\pm 5^\circ\text{C}$. The temperature is measured directly at the cell by a contact sensor or IR sensor.

7.2.2 During the degradation process performed under current injection (A) a power supply for a current of max. 10 A for a $156.75 \text{ mm} \times 156.75 \text{ mm}$ cell into the forward-biased *pn*-junction of the cell under study is required. This is approximately equivalent to a light exposure of the order of 1 sun at I_{sc} (I_{mpp} is included in this range as well). A light-tight housing is required for keeping the solar cell in the dark.

7.2.3 If the degradation is performed through homogeneous illumination (B), the solar cell has to be kept under open circuit conditions. An illumination reaching class C (IEC 60904-9) for the measurement of V_{oc} is recommended, but any spectral illumination is possible which fulfills the appropriate standards for solar illumination simulation.