

Solar Cells Reporting Summary

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► Experimental design

Please check: are the following details reported in the manuscript?

1. Dimensions

- | | | |
|--|--|---|
| Area of the tested solar cells | ☒ Yes
☐ No | 244.53 square centimeter, 274.3 square centimeter, 274.4 square centimeter and 274.4 square centimeter; Stated in Methods , Fig.S8 and Calibration certificate. |
| Method used to determine the device area | ☒ Yes
☐ No | The area of the calibration object is measured using an optical scanning system working in transmission mode and is traceable to a primary calibrated area standard (Calibration mark 50716-PTB-19 (FN001)), stated in Calibration certificate. |

2. Current-voltage characterization

- | | | |
|--|--|--|
| Current density-voltage (J-V) plots in both forward and backward direction | ☐ Yes
☒ No | Forward direction is enough for silicon cells |
| Voltage scan conditions
<i>For instance: scan direction, speed, dwell times</i> | ☒ Yes
☐ No | One current-voltage characteristics consists of 165 voltage steps and each step takes a time of 300 ms, stated in Calibration certificate. |
| Test environment
<i>For instance: characterization temperature, in air or in glove box</i> | ☒ Yes
☐ No | Standard testing conditions (AM1.5G, 100 mW/cm ² , 25°C) , stated in Calibration certificate. |
| Protocol for preconditioning of the device before its characterization | ☐ Yes
☒ No | Certified report not give this content. |
| Stability of the J-V characteristic
<i>Verified with time evolution of the maximum power point or with the photocurrent at maximum power point; see ref. 7 for details.</i> | ☐ Yes
☒ No | The layers and materials used for the solar cells are stable under standard testing conditions. |

3. Hysteresis or any other unusual behaviour

- | | | |
|---|--|--|
| Description of the unusual behaviour observed during the characterization | ☐ Yes
☒ No | A hysteresis between forward and reverse measurements was not observed, stated in Calibration certificate. |
| Related experimental data | ☐ Yes
☒ No | A hysteresis between forward and reverse measurements was not observed, stated in Calibration certificate. |

4. Efficiency

- | | | |
|---|--|--|
| External quantum efficiency (EQE) or incident photons to current efficiency (IPCE) | ☒ Yes
☐ No | Fig. 5 b |
| A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator | ☒ Yes
☐ No | This is done by a WPVS reference cell measured at ISFH, stated in Calibration certificate. |
| For tandem solar cells, the bias illumination and bias voltage used for each subcell | ☐ Yes
☒ No | They are not tandem solar cells. |

5. Calibration

- | | | |
|---|--|---|
| Light source and reference cell or sensor used for the characterization | ☒ Yes
☐ No | The sun simulator is adjusted using a WPVS reference cell, stated in Calibration certificate. |
|---|--|---|

Confirmation that the reference cell was calibrated and certified	☒ Yes ☐ No	The short circuit current of this reference cell was calibrated (primary standard "IV", Calibration mark 47086-PTB-21 (RD001)) under standard test conditions (1000 W/m ² , AM1.5G reference spectrum and 25 °C), stated in Calibration certificate.
Calculation of spectral mismatch between the reference cell and the devices under test	☐ Yes ☒ No	Reference cell and the as measured cells are the same kind of devices, no spectral mismatch.
6. Mask/aperture		
Size of the mask/aperture used during testing	☒ Yes ☐ No	All solar cells are conducted as total-area testing, stated in Calibration certificate.
Variation of the measured short-circuit current density with the mask/aperture area	☐ Yes ☒ No	All solar cells are conducted as total-area testing, stated in Calibration certificate.
7. Performance certification		
Identity of the independent certification laboratory that confirmed the photovoltaic performance	☒ Yes ☐ No	These cells used in our manuscript have been independently confirmed by ISFH;
A copy of any certificate(s) <i>Provide in Supplementary Information</i>	☒ Yes ☐ No	Figure S8 and Calibration certificate.
8. Statistics		
Number of solar cells tested	☐ Yes ☒ No	It only shows three typical champion solar cells certified by ISFH.
Statistical analysis of the device performance	☐ Yes ☒ No	It only shows three typical champion solar cells certified by ISFH.
9. Long-term stability analysis		
Type of analysis, bias conditions and environmental conditions <i>For instance: illumination type, temperature, atmosphere humidity, encapsulation method, preconditioning temperature</i>	☐ Yes ☒ No	long-term stability analysis has not yet been performed