nature portfolio

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# Solar Cells Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form is intended for publication with all accepted papers reporting the characterization of photovoltaic devices and provides structure for consistency and transparency in reporting. Some list items might not apply to an individual manuscript, but all fields must be completed for clarity.

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## Experimental design

**Please check the following details are reported in the manuscript, and provide a brief description or explanation where applicable.**

### 1. Dimensions

| | | |
|---|---|---|
| Area of the tested solar cells | ☒ Yes | 0.06 cm^2 |
| | ☐ No | *Explain why this information is not reported/not relevant.* |
| Method used to determine the device area | ☐ Yes | *Provide a description of the method and state where this information can be found in the text.* |
| | ☒ No | Laser testing |

### 2. Current-voltage characterization

| | | |
|---|---|---|
| Current density-voltage (J-V) plots in both forward and backward direction | ☒ Yes | Including forward and reverse scans |
| | ☐ No | *Explain why this information is not reported/not relevant.* |
| Voltage scan conditions | ☒ Yes | Forward and reverse range between 0V and 1.3V |
| | ☐ No | *Explain why this information is not reported/not relevant.* |
| Test environment | ☒ Yes | In glove box under 25 C |
| | ☐ No | *Explain why this information is not reported/not relevant.* |
| Protocol for preconditioning of the device before its characterization | ☐ Yes | *Provide a description of the protocol.* |
| | ☒ No | *Explain why this information is not reported/not relevant.* |
| Stability of the J-V characteristic | ☒ Yes | PCE of the unencapsulated PSCs measured at maximum power point under continuous one-sun illumination at 45 ± 5 °C in N2 atmosphere. |
| | ☐ No | *Explain why this information is not reported/not relevant.* |

### 3. Hysteresis or any other unusual behaviour

| | | |
|---|---|---|
| Description of the unusual behaviour observed during the characterization | ☒ Yes | We identify six kinds of hysteresis phenomena |
| | ☐ No | *Explain why this information is not reported/not relevant.* |
| Related experimental data | ☒ Yes | We verity simulated hysteresis phenomena by experiment preparation |
| | ☐ No | *Explain why this information is not reported/not relevant.* |

### 4. Efficiency

| | | |
|---|---|---|
| External quantum efficiency (EQE) or incident photons to current efficiency (IPCE) | ☐ Yes | *Provide a description of the technique used.* |
| | ☒ No | *Explain why this information is not reported/not relevant.* |
| A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator | ☐ Yes | *State where this information can be found in the text.* |
| | ☒ No | *Explain why this information is not reported/not relevant.* |

| | | |
|---|---|---|
| For tandem solar cells, the bias illumination and bias voltage used for each subcell | ☐ Yes<br>☒ No | *Provide a description of the measurement conditions.*<br>*Explain why this information is not reported/not relevant.* |

## 5. Calibration

| | | |
|---|---|---|
| Light source and reference cell or sensor used for the characterization | ☒ Yes<br>☐ No | Simulated AM 1.5 sunlight was generated by an Abet Class AAB AM 1.5G solar simulator. The light intensity (100 mW cm-2) was calibrated by an ISO 17025-certified KG3-filtered silicon reference cell.<br>*Explain why this information is not reported/not relevant.* |
| Confirmation that the reference cell was calibrated and certified | ☒ Yes<br>☐ No | KG3-filtered silicon reference cell<br>*Explain why this information is not reported/not relevant.* |
| Calculation of spectral mismatch between the reference cell and the devices under test | ☒ Yes<br>☐ No | *Provide a value of the spectral mismatch and/or a description of how it has been taken into account in the measurements.*<br>*Explain why this information is not reported/not relevant.* |

## 6. Mask/aperture

| | | |
|---|---|---|
| Size of the mask/aperture used during testing | ☒ Yes<br>☐ No | a device area of 0.06 cm2<br>*Explain why this information is not reported/not relevant.* |
| Variation of the measured short-circuit current density with the mask/aperture area | ☐ Yes<br>☒ No | *Report the difference in the short-circuit current density values measured with the mask and aperture area.*<br>*Explain why this information is not reported/not relevant.* |

## 7. Performance certification

| | | |
|---|---|---|
| Identity of the independent certification laboratory that confirmed the photovoltaic performance | ☐ Yes<br>☒ No | *Identify the independent certification laboratory.*<br>*Explain why this information is not reported/not relevant.* |
| A copy of any certificate(s) | ☐ Yes<br>☒ No | *Certificate copies should be provided in the Supplementary information. Please state the supplementary item number.*<br>*Explain why this information is not reported/not relevant.* |

## 8. Statistics

| | | |
|---|---|---|
| Number of solar cells tested | ☐ Yes<br>☒ No | *Report how many solar cells have been tested, specifying the number of individual substrates.*<br>*Explain why this information is not reported/not relevant.* |
| Statistical analysis of the device performance | ☐ Yes<br>☒ No | *State where this information can be found in the text.*<br>*Explain why this information is not reported/not relevant.* |

## 9. Long-term stability analysis

| | | |
|---|---|---|
| Type of analysis, bias conditions and environmental conditions | ☒ Yes<br>☐ No | PCE of the unencapsulated PSCs measured at maximum power point under continuous one-sun illumination at 45 ± 5 °C in N2 atmosphere.<br>*Explain why this information is not reported/not relevant.* |