

Solar Cells Reporting Summary

Nature Research 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.

For further information on Nature Research policies, including our [data availability policy](#), see [Authors & Referees](#).

► Experimental design

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

1. Dimensions

- | | | |
|--|--|---|
| Area of the tested solar cells | ☒ Yes
☐ No | "Device characterizations" section |
| Method used to determine the device area | ☒ Yes
☐ No | The devices were masked with a metal aperture to define an active area. |

2. Current-voltage characterization

- | | | |
|--|--|--|
| Current density-voltage (J-V) plots in both forward and backward direction | ☒ Yes
☐ No | Fig. 1b, Fig. 4c, Supplementary Fig. 18, Supplementary Fig. 20, Supplementary Fig. 21, and Supplementary Fig. 25 |
| Voltage scan conditions
<i>For instance: scan direction, speed, dwell times</i> | ☒ Yes
☐ No | "Device characterizations" section |
| Test environment
<i>For instance: characterization temperature, in air or in glove box</i> | ☒ Yes
☐ No | "Device characterizations" section |
| Protocol for preconditioning of the device before its characterization | ☐ Yes
☒ No | No preconditioning is required before characterization. |
| 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 | Fig. 1b and Fig. 4c |

3. Hysteresis or any other unusual behaviour

- | | | |
|---|--|--|
| Description of the unusual behaviour observed during the characterization | ☒ Yes
☐ No | Minor hysteresis was observed in the devices performance. |
| Related experimental data | ☒ Yes
☐ No | Fig. 1b, Fig. 4c, Supplementary Fig. 18, Supplementary Fig. 20, Supplementary Fig. 21, and Supplementary Fig. 25 |

4. Efficiency

- | | | |
|---|--|---|
| External quantum efficiency (EQE) or incident photons to current efficiency (IPCE) | ☒ Yes
☐ No | EQE curve was provided (Supplementary Fig. 23). |
| A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator | ☒ Yes
☐ No | The integrated Jsc from EQE were agree well with the Jsc determined from the J-V measurements |
| For tandem solar cells, the bias illumination and bias voltage used for each subcell | ☐ Yes
☒ No | No tandem device was reported in this work. |

5. Calibration

- | | | |
|---|--|--|
| Light source and reference cell or sensor used for the characterization | ☒ Yes
☐ No | "Device characterizations" section |
| Confirmation that the reference cell was calibrated and certified | ☒ Yes
☐ No | "Device characterizations" section. The reference cells were certified by NREL PV Performance Calibration group. |

Calculation of spectral mismatch between the reference cell and the devices under test

☒ Yes
☐ No

The intensity of the solar simulator was calibrated with a KG5 filtered Si reference solar cell that was certified by NREL PV Performance Characterization Team, and the spectral mismatch factor was minimized to 0.9923.

6. Mask/aperture

Size of the mask/aperture used during testing

☒ Yes
☐ No

"Device characterizations" section

Variation of the measured short-circuit current density with the mask/aperture area

☐ Yes
☒ No

The aperture area is fixed for each kind of device.

7. Performance certification

Identity of the independent certification laboratory that confirmed the photovoltaic performance

☐ Yes
☒ No

No record efficiency is claimed. Our focus is on reporting a new general methodology for PSC processing and providing an understanding of how it works.

A copy of any certificate(s)
Provide in Supplementary Information

☐ Yes
☒ No

No record efficiency is claimed. Our focus is on reporting a new general methodology for PSC processing and providing an understanding of how it works.

8. Statistics

Number of solar cells tested

☒ Yes
☐ No

Supplementary Fig. 22, Supplementary Fig. 24, and Supplementary Fig. 26

Statistical analysis of the device performance

☒ Yes
☐ No

Supplementary Fig. 22, Supplementary Fig. 24, and Supplementary Fig. 26

9. Long-term stability analysis

Type of analysis, bias conditions and environmental conditions

☒ Yes
☐ No

Fig. 3c

For instance: illumination type, temperature, atmosphere humidity, encapsulation method, preconditioning temperature