

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 It can be found in the part of 'Methods'.
- Method used to determine the device area ☒ Yes ☐ No The method can be found in the part of 'Methods'.

2. Current-voltage characterization

- Current density-voltage (J-V) plots in both forward and backward direction ☒ Yes ☐ No It can be found in both text and figures: Fig.1-3.
- Voltage scan conditions ☒ Yes ☐ No It can be found in the part of 'Methods'.
- For instance: scan direction, speed, dwell times*
- Test environment ☒ Yes ☐ No It can be found in the part of 'Methods'.
- For instance: characterization temperature, in air or in glove box*
- Protocol for preconditioning of the device before its characterization ☐ Yes ☒ No The device is stable and does not need special precondition.
- Stability of the J-V characteristic ☒ Yes ☐ No It can be seen in Fig. 3c.
- Verified with time evolution of the maximum power point or with the photocurrent at maximum power point; see ref. 7 for details.*

3. Hysteresis or any other unusual behaviour

- Description of the unusual behaviour observed during the characterization ☒ Yes ☐ No Fig. 3a described the behavior of hysteresis.
- Related experimental data ☒ Yes ☐ No Fig. 3a, Table 1

4. Efficiency

- External quantum efficiency (EQE) or incident photons to current efficiency (IPCE) ☒ Yes ☐ No Fig. 3b, Fig. 3d
- A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator ☒ Yes ☐ No Fig. 3d, Fig. 3e
- For tandem solar cells, the bias illumination and bias voltage used for each subcell ☐ Yes ☒ No No tandem solar cells are involved here.

5. Calibration

- Light source and reference cell or sensor used for the characterization ☒ Yes ☐ No It can be found in the part of 'Methods'.
- Confirmation that the reference cell was calibrated and certified ☒ Yes ☐ No It can be found in the part of 'Methods'.

Calculation of spectral mismatch between the reference cell and the devices under test	☐ Yes ☒ No	The solar simulator is 3A grade, i.e., the spectral mismatch is below 2%.
6. Mask/aperture		
Size of the mask/aperture used during testing	☒ Yes ☐ No	It can be found in the part of 'Methods'.
Variation of the measured short-circuit current density with the mask/aperture area	☒ Yes ☐ No	Table 1
7. Performance certification		
Identity of the independent certification laboratory that confirmed the photovoltaic performance	☐ Yes ☒ No	We are not claiming the record efficiency.
A copy of any certificate(s) <i>Provide in Supplementary Information</i>	☐ Yes ☒ No	We are not claiming the record efficiency.
8. Statistics		
Number of solar cells tested	☒ Yes ☐ No	Supplementary Figure 8
Statistical analysis of the device performance	☒ Yes ☐ No	Supplementary Figure 8
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	Supplementary figure 9