

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 Methods section: 0.1 cm².
- Method used to determine the device area Yes No Methods section: Device area is defined by cross-overlap of the 0.2 cm wide patterned ITO bar and the 0.5 cm wide Al/Cu bar deposited through a shadow mask.

2. Current-voltage characterization

- Current density-voltage (J-V) plots in both forward and backward direction Yes No Fig. 1b
- Voltage scan conditions Yes No Main text: the voltage was scanned both in forward direction from -0.2 V to 1.2 V and reverse direction from 1.2 V to -0.2 V with a scan speed 0.02 V/s
For instance: scan direction, speed, dwell times
- Test environment Yes No Main text: in N₂-filled glove box
For instance: characterization temperature, in air or in glove box
- Protocol for preconditioning of the device before its characterization Yes No Main text: no preconditioning
- Stability of the J-V characteristic Yes No Supplementary Fig. 3: steady-state PCEs were obtained by tracking the maximum power point.
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 Main text: negligible hysteresis and no other unusual behavior
- Related experimental data Yes No Not relevant

4. Efficiency

- External quantum efficiency (EQE) or incident photons to current efficiency (IPCE) Yes No Fig. 1d.
- A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator Yes No Main text: the integrated J_{sc} obtained from the EQE spectra agrees well with the J_{sc} value obtained from the J-V curves under the simulator within 5% deviation
- For tandem solar cells, the bias illumination and bias voltage used for each subcell Yes No Not relevant.

5. Calibration

- Light source and reference cell or sensor used for the characterization Yes No Methods section: light source: a SS-F5-3A solar simulator (Enli Technology CO., Ltd.) for AM 1.5G illumination (100 mW cm⁻²); reference cell: a standard Si solar cell (SRC-00036)
- Confirmation that the reference cell was calibrated and certified Yes No Methods section: the reference cell is calibrated and certified by Enli Technology

Calculation of spectral mismatch between the reference cell and the devices under test	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	1.017
6. Mask/aperture		
Size of the mask/aperture used during testing	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Methods section: non-reflective mask with area of 0.049 cm ² was also used to define the cell area
Variation of the measured short-circuit current density with the mask/aperture area	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Not relevant
7. Performance certification		
Identity of the independent certification laboratory that confirmed the photovoltaic performance	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	The photovoltaic performance of our devices was not confirmed from independent certification laboratories
A copy of any certificate(s) <i>Provide in Supplementary Information</i>	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Not relevant
8. Statistics		
Number of solar cells tested	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Main text: more than 20 devices for each kind of devices were tested
Statistical analysis of the device performance	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Fig. 1c, Table 1
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>	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Fig. 5a: a shelf-life test in ambient with 40% - 50% and 75% - 85% RH without any encapsulation