

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	The active area of devices was 0.0256 cm ² .
Method used to determine the device area	☒ Yes ☐ No	The active area of the solar cells was defined by an opaque metal mask with square aperture of the area of 0.0256 cm ² .

2. Current-voltage characterization

Current density-voltage (J-V) plots in both forward and backward direction	☐ Yes ☒ No	Organic solar cells do not have hysteresis problem.
Voltage scan conditions <i>For instance: scan direction, speed, dwell times</i>	☒ Yes ☐ No	The voltage scan rate and scan step were 20 mV s ⁻¹ and 20 mV for devices.
Test environment <i>For instance: characterization temperature, in air or in glove box</i>	☒ Yes ☐ No	The J-V characteristic was performed at room temperature in N ₂ -filled glovebox.
Protocol for preconditioning of the device before its characterization	☐ Yes ☒ No	No preconditioning was applied.
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 operating stability of devices were performed at the MPP and it could be found in Fig. 4c and Supplementary Fig. 21-23.

3. Hysteresis or any other unusual behaviour

Description of the unusual behaviour observed during the characterization	☐ Yes ☒ No	No unusual behaviour was found in this research.
Related experimental data	☐ Yes ☒ No	No related experimental data.

4. Efficiency

External quantum efficiency (EQE) or incident photons to current efficiency (IPCE)	☒ Yes ☐ No	See Fig. 2f in manuscript.
A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator	☒ Yes ☐ No	The integrated J _{sc} values from the EQE curves in Fig. 2f matched well with those measured from the J-V curves.
For tandem solar cells, the bias illumination and bias voltage used for each subcell	☐ Yes ☒ No	No tandem solar cell was fabricated in this research.

5. Calibration

Light source and reference cell or sensor used for the characterization	☒ Yes ☐ No	The J-V characteristic was performed by the solar simulator (SS-F5-3A, Enlitech) along with AM 1.5G spectra which intensity was calibrated by the certified standard silicon solar cell (SRC-2020, Enlitech) at 100 mW/cm ² .
Confirmation that the reference cell was calibrated and certified	☒ Yes ☐ No	The reference cell (SRC-2020, Enlitech) was certified.

Calculation of spectral mismatch between the reference cell and the devices under test	☐ Yes ☒ No	No spectral mismatch calculation was performed in our lab.
6. Mask/aperture		
Size of the mask/aperture used during testing	☒ Yes ☐ No	The area of the mask is 0.0256 cm ² .
Variation of the measured short-circuit current density with the mask/aperture area	☐ Yes ☒ No	It was not found in this research.
7. Performance certification		
Identity of the independent certification laboratory that confirmed the photovoltaic performance	☐ Yes ☒ No	It was not necessary in this research.
A copy of any certificate(s) <i>Provide in Supplementary Information</i>	☐ Yes ☒ No	It was not necessary in this research.
8. Statistics		
Number of solar cells tested	☒ Yes ☐ No	For the J-V characteristics, over 8 devices were tested for each condition. In the shelf-stability measurement, six devices were tested. In the thermal stability and MPP stability, five and three devices were tested respectively.
Statistical analysis of the device performance	☒ Yes ☐ No	See Supplementary Table 5, 6 and 8 in supplementary information.
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	For the thermal aging test, devices were placed on the hotplate heating at 60°C in N ₂ -filled glovebox, respectively. For the thermal-circulation stability, devices were placed in a vacuum chamber with the standard ISOS-T-3. For the UV-irradiation aging test, devices were placed under the 365 nm UV light.