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## 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   | <b>X</b> Yes | Section "OSC device fabrication and measurement"   |
|    |  | No           | Explain why this information is not reported/not relevant.   |
|    | Method used to determine the device area   | X Yes        | The electronic active area of the cell is defined by the overlap of the ITO electrode and metal electrode.   |
|    |  |              | Explain why this information is not reported/not relevant.   |
| 2. | Current-voltage characterization   |              |  |
|    | Current density-voltage (J-V) plots in both forward and backward direction   | Yes          | State where this information can be found in the text.   |
|    |  | × No         | Generally, organic photovoltaic devices do not have forward and backward problems. And we only scan the device in forward direction.   |
|    | Voltage scan conditions<br>For instance: scan direction, speed, dwell times  | 🗴 Yes        | Section "OSC device fabrication and measurement"   |
|    |  | No           | Explain why this information is not reported/not relevant.   |
|    | Test environment<br>For instance: characterization temperature, in air or in glove<br>box  | Yes          | Our devices were characterized at room temperature (ca. 25 Celsius degree) in glove box.   |
|    |  |              | Explain why this information is not reported/not relevant.   |
|    | Protocol for preconditioning of the device before its characterization   | Yes          | State where this information can be found in the text.   |
|    |  | × No         | No preconditioning protocol  |
|    | Stability of the J-V characteristic<br>Verified with time evolution of the maximum power point or<br>with the photocurrent at maximum power point; see <u>ref. 7</u><br>for details. | Yes          | No hysteresis or other unusual behaviour was observed during the characterization of the solar cells. In general, organic solar cells do not have hystereisis problems.              |
|    |  |              | We only tested the long-term stability.  |
| 3. | Hysteresis or any other unusual behaviour  |              |  |
|    | Description of the unusual behaviour observed during the characterization  | Yes          | State where this information can be found in the text.   |
|    |  | × No         | No hysteresis or other unusual behaviour was observed during the characterization of the solar cells. In general, organic solar cells do not have hysteresis problems.               |
|    | Related experimental data  | Yes          | State where this information can be found in the text.   |
|    |  | X No         | No hysteresis or other unusual behaviour was observed during the characterization of the solar cells.  |
| 4. | Efficiency   |              |  |
|    | External quantum efficiency (EQE) or incident photons to current efficiency (IPCE)   | Yes          | The external quantum efficiency (EQE) spectra of OSCs are recorded using Enli QE-<br>R3011 (Enli Technology Co., Ltd Taiwan).  |
|    |  |              | Explain why this information is not reported/not relevant.   |
|    | A comparison between the integrated response under<br>the standard reference spectrum and the response<br>measure under the simulator  | Yes          | There are less than 5% errors between the integrated response under the standard reference spectrum and the response measure under the simulator. We give details in the manuscript. |
|    |  |              |  |

Explain why this information is not reported/not relevant.

For tandem solar cells, the bias illumination and bias voltage used for each subcell

#### 5. Calibration

Light source and reference cell or sensor used for the characterization

Confirmation that the reference cell was calibrated and certified

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

6. Mask/aperture

Size of the mask/aperture used during testing

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

7. Performance certification

Identity of the independent certification laboratory that confirmed the photovoltaic performance

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

8. Statistics

Number of solar cells tested

Statistical analysis of the device performance

9. Long-term stability analysis

Type of analysis, bias conditions and environmental conditions

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

| Section "OSC device fabrication and measurement"  |
|---|
| Explain why this information is not reported/not relevant.  |
| The relative expanded uncertainty resulting of the relative combined standard uncertainty multiplied with a coverage factor k = 2 is specified. It corresponds to a level of confidence of 95%. |
| We do not have the detailed information for the method.   |
|   |
| State where this information can be found in the text.  |
| We did not use a mask during testing and the device effective area was obtained by its crossed area of the bottom and top electrodes.   |
| State where this information can be found in the text.  |
| We did not use a mask during testing.   |
|   |
| The PCE was certified by NIM, China, using a 3.152 mm2 mask.  |
|   |
|   |

Yes State where this information can be found in the text. We only fabricated single junction solar cells.

Section "OSC device fabrication and measurement"

Explain why this information is not reported/not relevant.

× No

X Yes

No

× Yes

No

No

No

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We have tested ten solar cells for each type of OSCs, and the average PCE of OSCs are obtained from ten independent cells. Explain why this information is not reported/not relevant.

X Yes Statistical results of the devices are listed in Table 1,2 and Supplementary Table 1-9. Explain why this information is not reported/not relevant.

#### X Yes See "Supplementary Figure 6."

Explain why this information is not reported/not relevant.