## Supplementary information

# High efficient ternary organic solar cell with morphology-compatible polymers

*Jiangquan Mai, Haipeng Lu, Tsz-Ki Lau, Shih-Hao Peng, Chain-Shu Hsu, Wenqiang Hua, Ni Zhao, Xudong Xiao, Xinhui Lu**

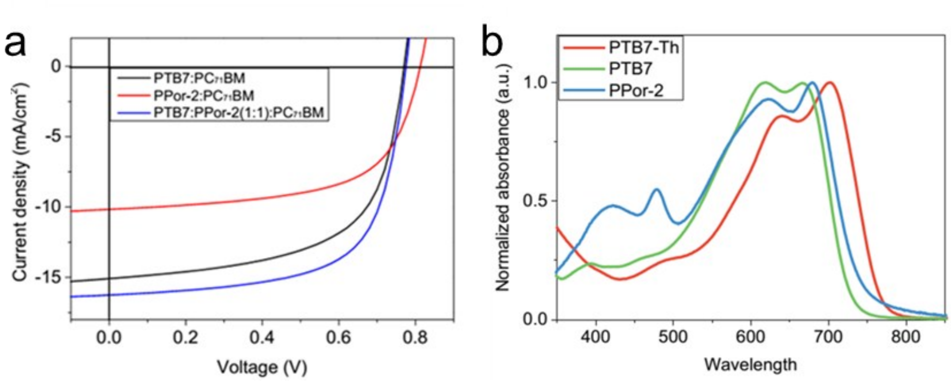


Figure S1. (a) The JV curves of PTB7:$PC_{71}BM$, PPor-2:$PC_{71}BM$ and PTB7:PPor-2(1:1): $PC_{71}BM$ solar cells;(b) the UV-Vis absorption spectrums of PTB7, PTB7-Th and PPor-2;

Table S1. GISAXS profile model fitting results ($L_{polymer}$ is obtained from GIWAXS).

| | ξ (Å) | D | $2R_{gPC71BM}$ (Å) | $L_{Polymer}$ (Å) |
|---|---|---|---|---|
| PPor-2:PC71BM | 165 | 1.87 | 632 | 96 |
| PTB7-Th:PC71BM | 56 | 2.09 | 435 | 58 |
| Ppor-2:PTB7-Th(1:1):PC71BM | 78 | 2.13 | 602 | 50 |

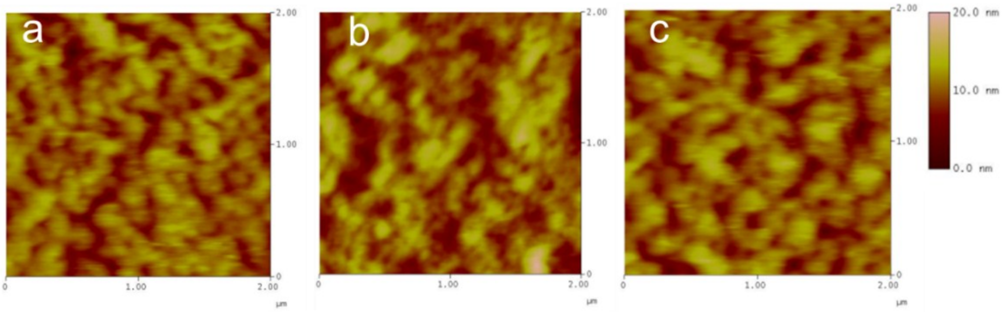


Figure S2. Atomic force microscope (AFM) images of (a) PTB7-Th:PC71BM, (b) PTB7-Th:PPor-2(1:1):PC71BM and (c) PPor-2:PC71BM blend films. The root mean square average (RMS) of a-c images are 1.9 nm, 2.3 nm and 2.0 nm respectively.

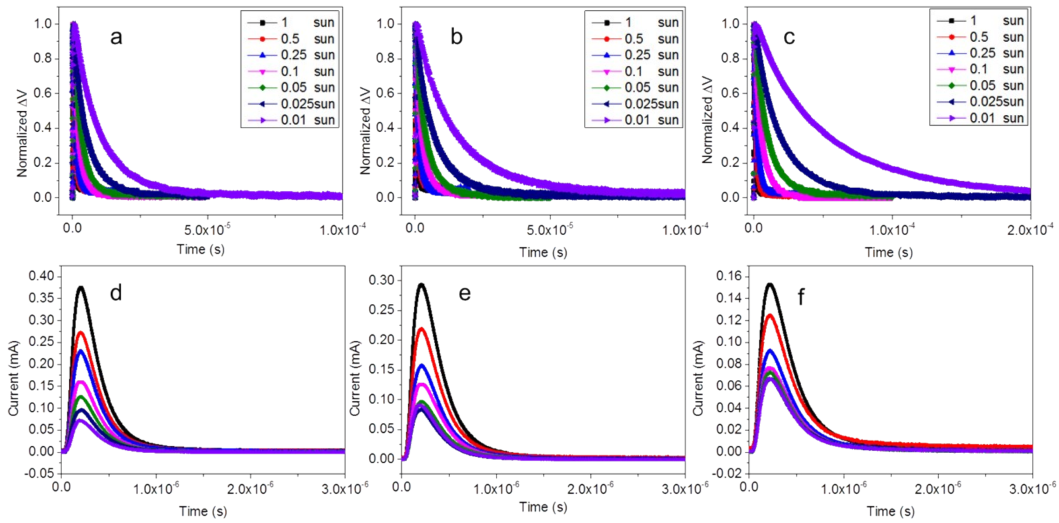


Figure S3. Transient photovoltage(TPV) and transient photocurrent(TPC) data measured on (a,d) PTB7-Th:PC71BM solar cell, (b,e), PTB7-Th:PPor-2:PC71BM solar cell, (c,f) PPor-2:PC71BM solar cell. For the same cell, we used the same intensity of laser used in TPV to conduct TPC measurement and corresponding curves were labeled with the same color. The laser intensity used for different cells was a little different because solar cells with different $V_{oc}$s required different laser intensities to achieve similar ΔV.

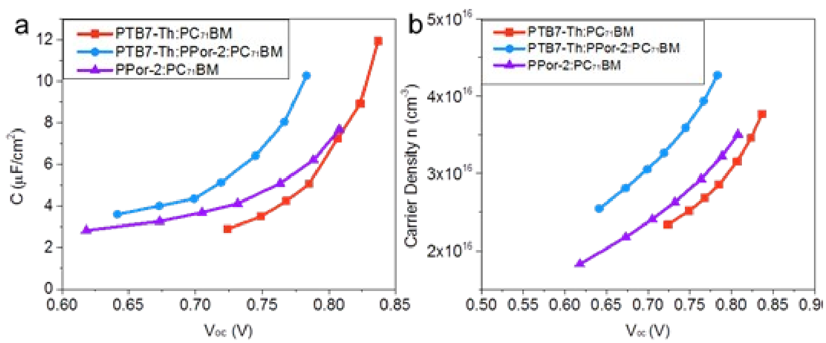


Figure S4. (a) Differential capacitance per unit area against $V_{oc}$; (b) Carrier density against $V_{oc}$.

We measured the transient photovoltage (TPV) under different background light intensity varying from 0.01 to 1 sun.[1] A laser with 633 nm wavelength, gave a pulse illumination on the solar cell so the $V_{oc}$ could have a very small increase $\Delta V \approx 10$mV. As shown in Figure S3 a-c, the decay kinetic of the photovoltage follows a mono-exponential decay: $\delta V = A\ exp(-\tau/t)$, where $t$ is the time and $\tau$ is the decay time constant. Because $\delta V$ is generated by the laser exited charge carrier, $\tau$ also represents the life time of the carrier in the film. Then, the same intensity of laser light was used to measure transient photocurrent (TPC) and obtained the charge density following the method developed by Shuttle et al.[2] Figure S3 d-f shows the TPC data. The amount of charge introduced by the laser light $\Delta Q$ was extracted by integrate the current in respect of time. The differential capacitance was calculated by $C=\Delta Q/\Delta V$ under the same intensity of laser pulse. Figure S4a shows the differential capacitance in term of different $V_{oc}$ controlled by varying background intensity from approximately 0.01 to 1.0 sun. Than the carrier density $n$ can be calculated with the following equation:

$$n = \frac{1}{eAd}\int_0^{V_{oc}} CdV \qquad (1)$$

where, $e$ is the electron charge, $A$ is the device area, and $d$ is the active layer thickness.
Figure S4b shows the carrier densities under different $V_{oc}$ for all the three devices. And Figure 5a shows the carrier life times under different carrier densities.

Reference

1. X. Guo, N. Zhou, S. J. Lou, J. Smith, D. B. Tice, J. W. Hennek, R. P. Ortiz, J. T. L. Navarrete, S. Li, J. Strzalka, L. X. Chen, R. P. H. Chang, A. Facchetti and T. J. Marks, *Nat. Photonics*, 2013, 7, 825-833.
2. C. G. Shuttle, A. Maurano, R. Hamilton, B. O'Regan, J. C. de Mello and J. R. Durrant, *Appl. Phys. Lett.*, 2008, 93, 183501.