

## **Supporting Information**

### **Tuning Surface Wettability of Buffer Layers by Incorporating Polyethylene Glycols for Enhanced Performances of Perovskite Solar Cells**

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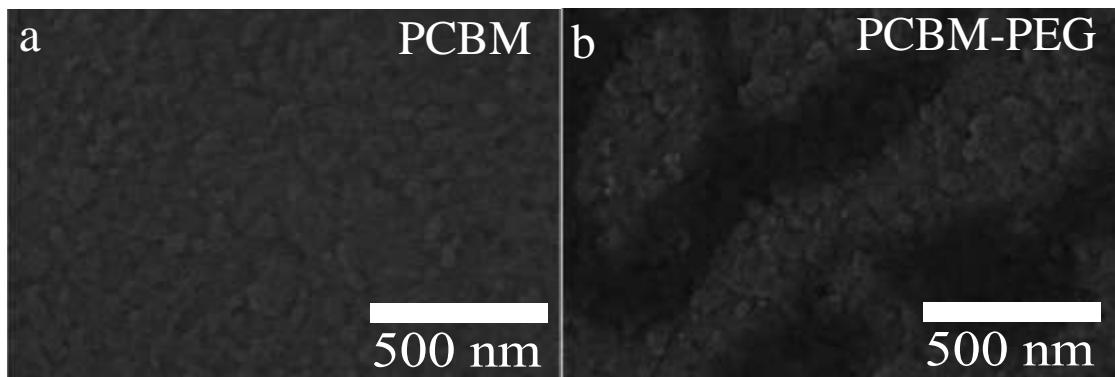
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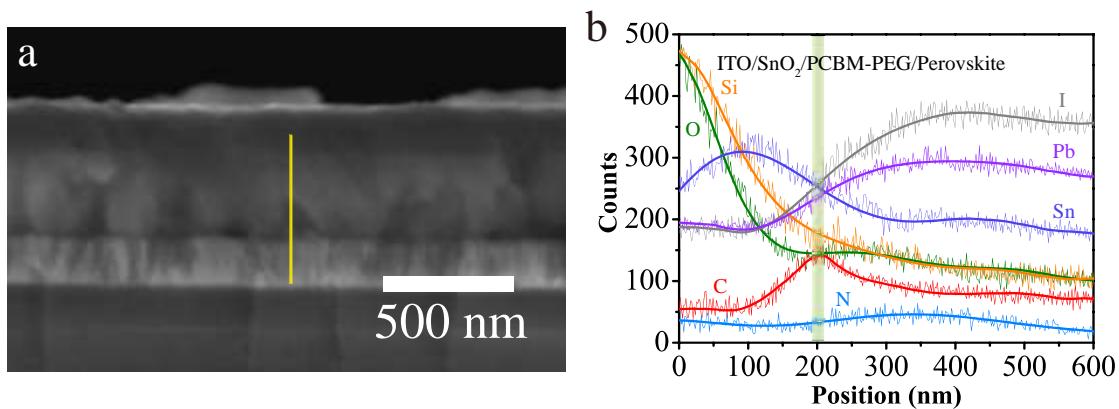
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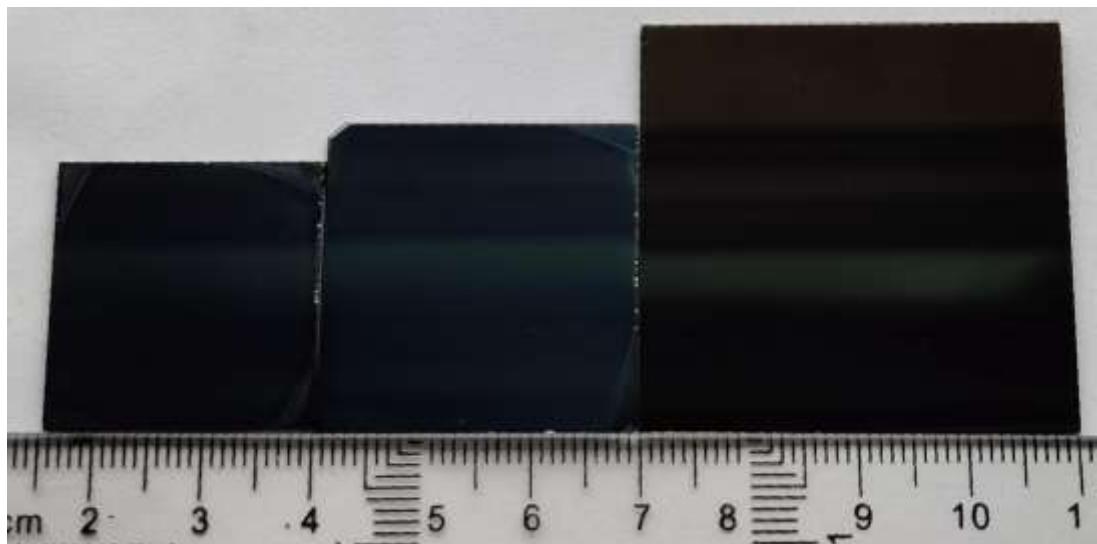
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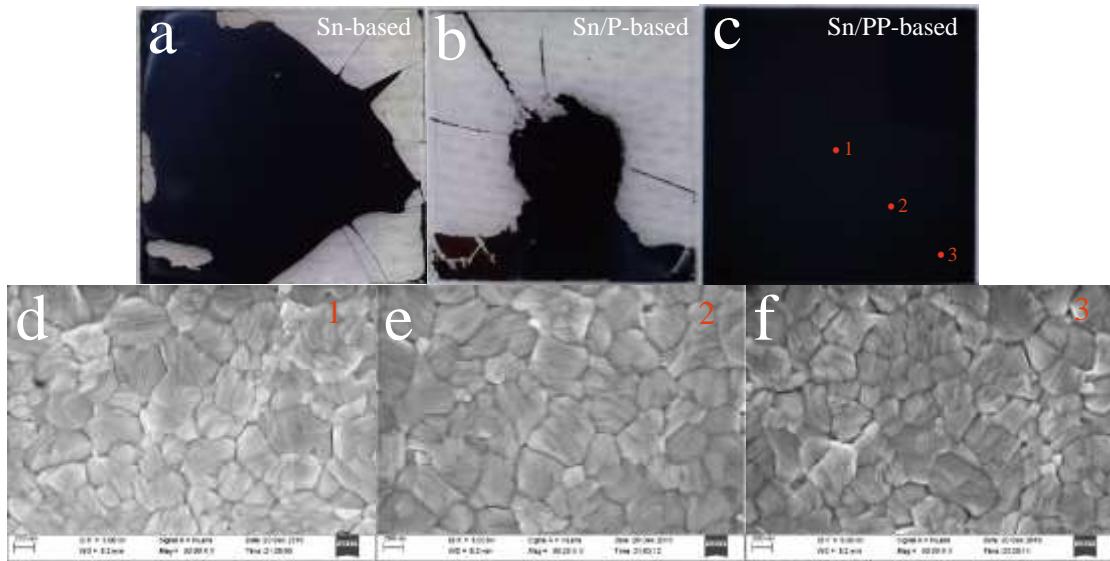
**Figure S1** FESEM images of (a) PCBM and (b) PCBM-PEG.



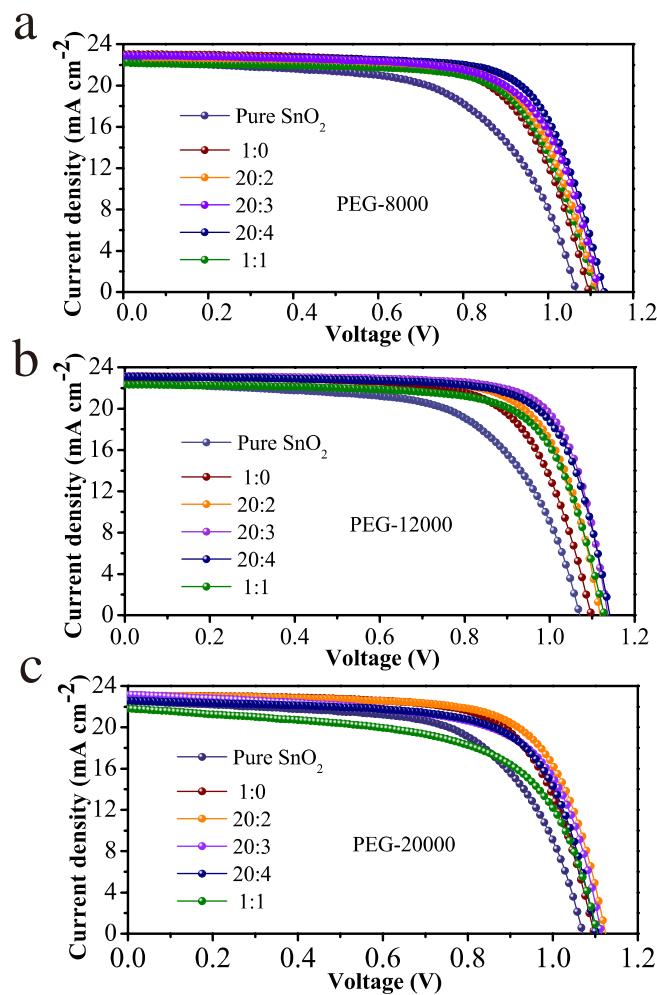
**Figure S2** (a) A FESEM image and (b) corresponding EDS line scanning spectrogram of cross section (ITO/SnO<sub>2</sub>/PCBM-PEG/Perovskite).



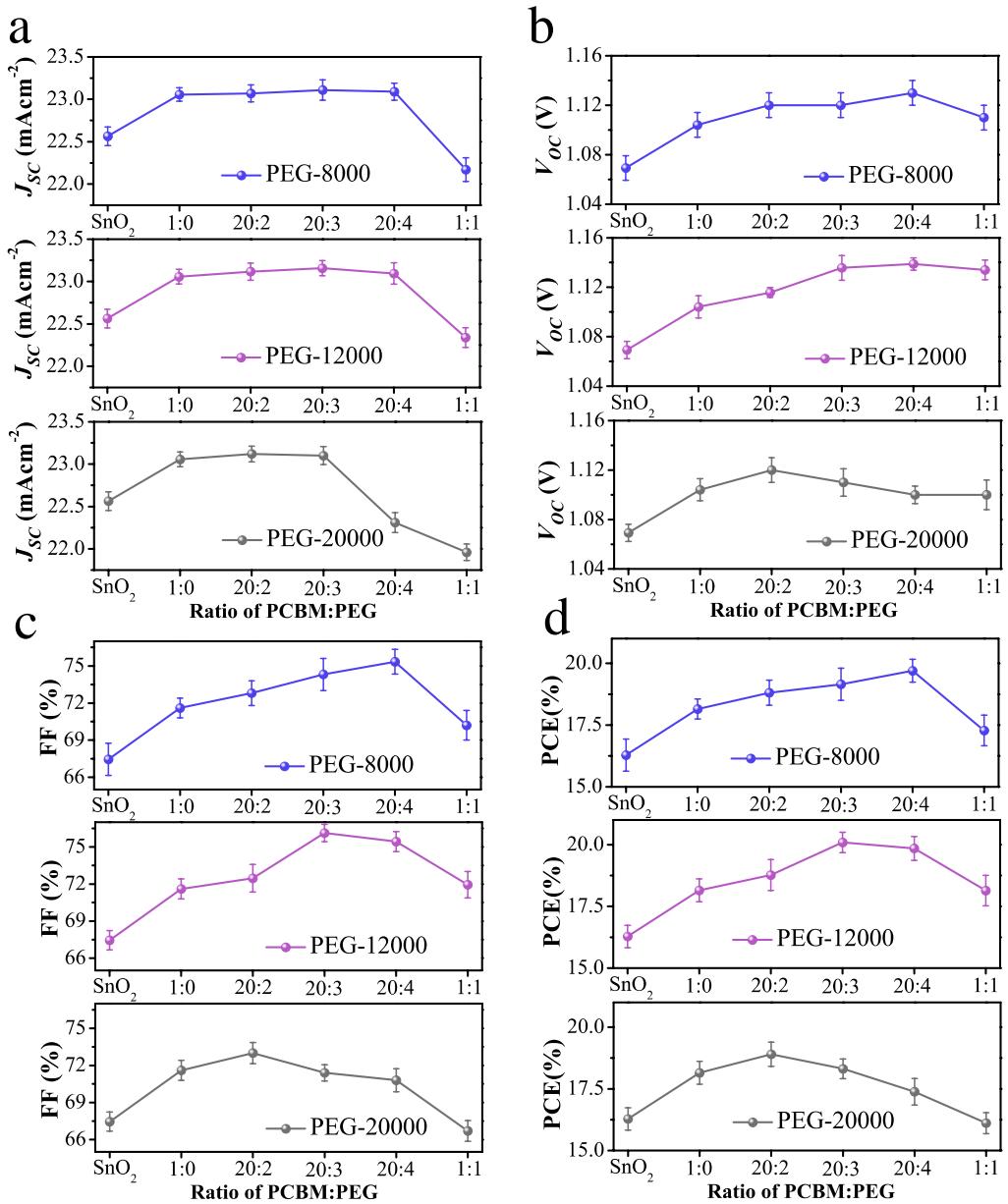
**Figure S3** 2.5 x 2.5 cm, 3 x 3 cm and 4 x 4 cm Sn/PP-based perovskite films.



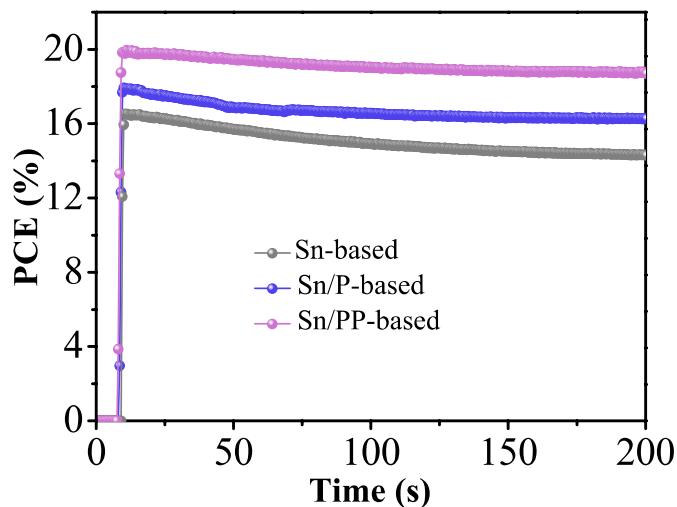
**Figure S4** (a-c)  $2 \times 2$  cm Sn-based, Sn/P-based and Sn/PP-based perovskite film. (d-f) Top-view SEM images taken at 1,2 and 3 locations, respectively.



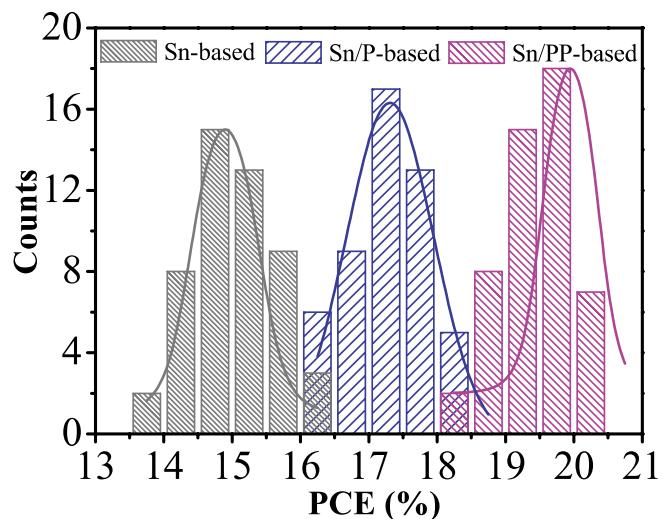
**Figure S5**  $J$ - $V$  characteristic curves of PSCs treated with PEG at different molecular weights, (a) PEG-8000, (b) PEG-12000 and (c) PEG-20000.



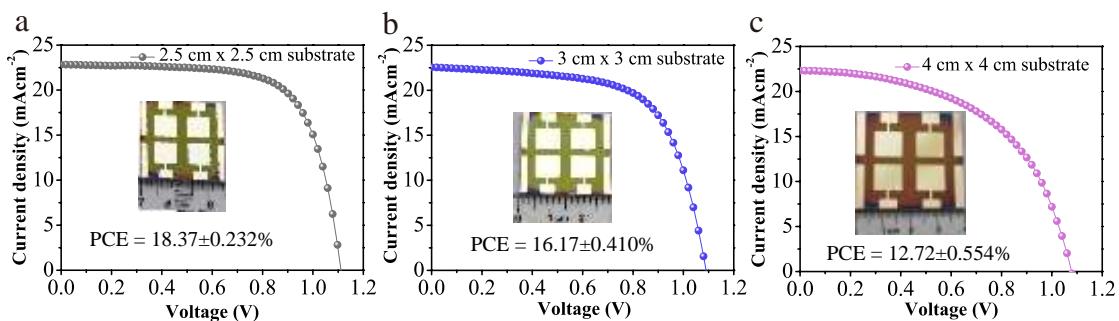
**Figure S6** Curves of photovoltaic performance as a function of PEG/PCBM proportions, (a)  $J_{SC}$ , (b)  $V_{OC}$ , (c) FF and (d) PCE.



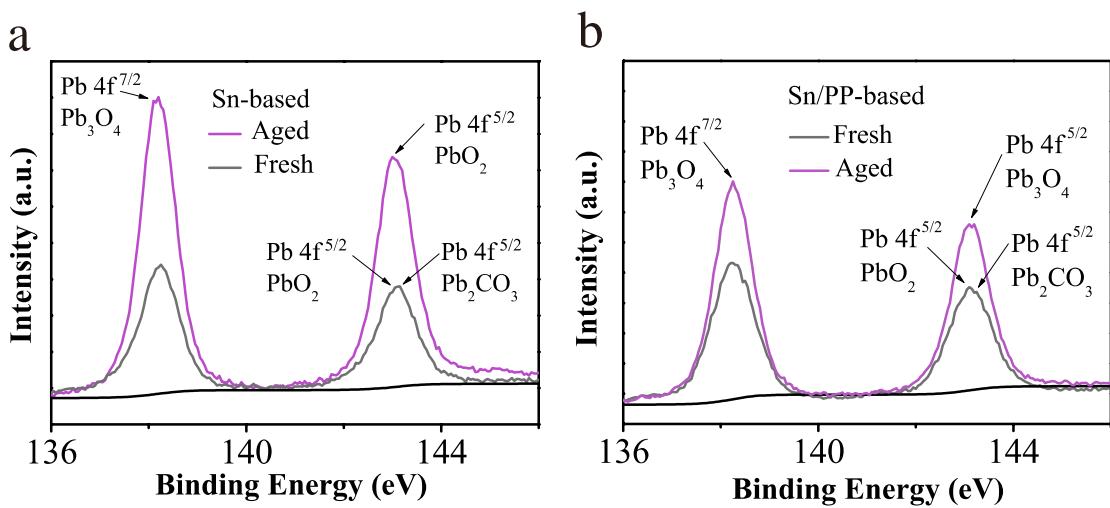
**Figure S7** Stabilized power output of three champion cells at the maximum power point for 200 s.



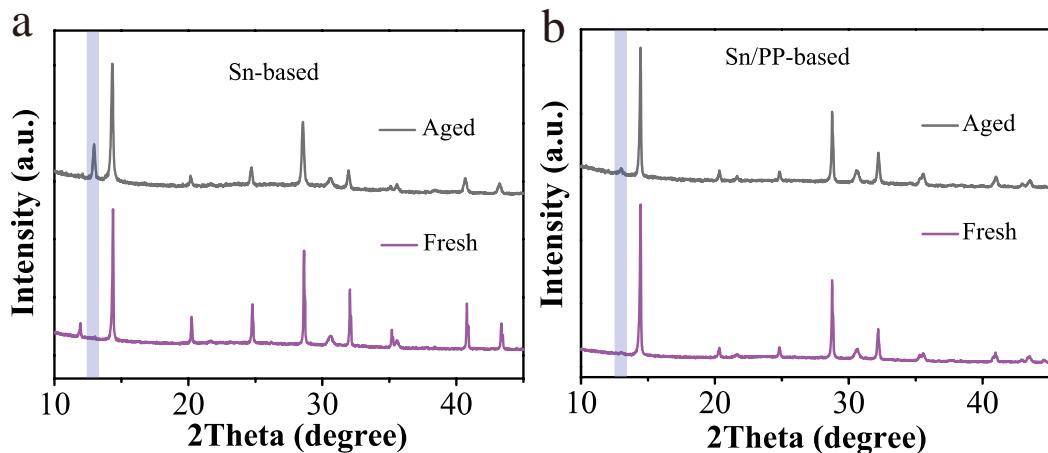
**Figure S8** Histogram of PCE values among 50 devices.



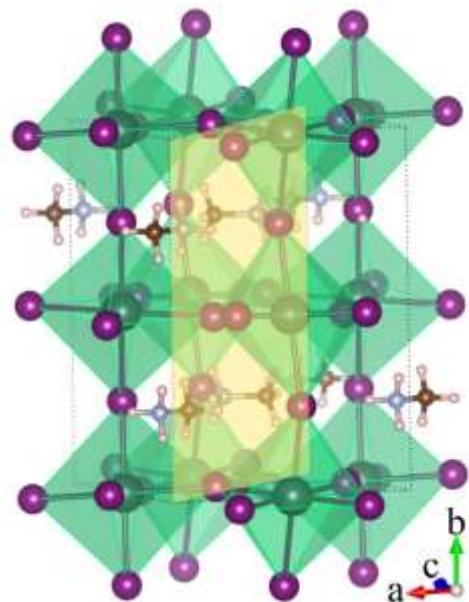
**Figure S9**  $J$ - $V$  characteristic curves of devices based on substrate of three size (a) 2.5 x 2.5 cm, (b) 3 x 3 cm, (c) 4 x 4 cm.



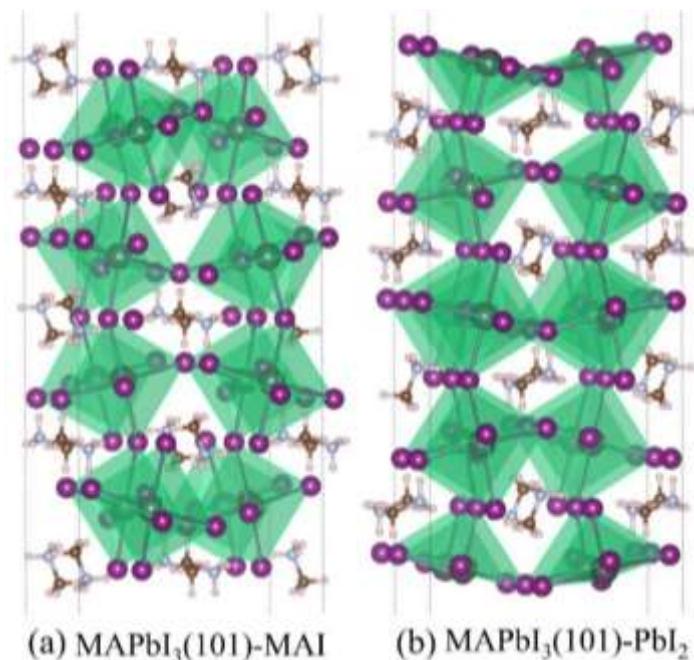
**Figure S10** Core level XPS spectra of  $\text{Pb } 4f$  for fresh and 200 hours aged Sn-based perovskite films (a) and (b) Sn/PP-based perovskite films.



**Figure S11** XRD patterns of fresh and 200 hours aged (a) Sn-based and (b) Sn/PP-based perovskite films.



**Figure S12** Orthorhombic  $\text{MAPbI}_3$  slab models.



**Figure S13** Two kinds of  $\text{MAPbI}_3$  models. (a)  $\text{MAPbI}_3$  surface is MAI. (b)  $\text{MAPbI}_3$  surface is  $\text{PbI}_2$ .

**Table S1** Photovoltaic parameters of  $\text{MAPbI}_3$  solar cells with PEG-8000 at different substrates obtain in the reverse scan direction.

Devices	$V_{OC}$ (V)	$J_{SC}$ ( $\text{mA cm}^{-2}$ )	FF (%)	PCE (%)
Pure $\text{SnO}_2$	$1.07 \pm 0.007$	$22.57 \pm 0.110$	$67.4 \pm 0.775$	$16.28 \pm 0.457$
1:0	$1.10 \pm 0.009$	$23.05 \pm 0.087$	$71.6 \pm 0.810$	$18.15 \pm 0.464$
20:2	$1.12 \pm 0.010$	$23.07 \pm 0.112$	$72.8 \pm 0.542$	$18.81 \pm 0.340$
20:3	$1.12 \pm 0.006$	$23.11 \pm 0.094$	$74.0 \pm 0.718$	$19.15 \pm 0.419$
20:4	$1.13 \pm 0.010$	$23.09 \pm 0.120$	$75.5 \pm 0.851$	$19.70 \pm 0.502$
1:1	$1.11 \pm 0.011$	$22.17 \pm 0.108$	$70.2 \pm 0.995$	$17.28 \pm 0.570$

**Table S2** Photovoltaic parameters of  $\text{MAPbI}_3$  solar cells with PEG-12000 at different substrates obtain in the reverse scan direction.

Devices	$V_{OC}$ (V)	$J_{SC}$ ( $\text{mA cm}^{-2}$ )	FF (%)	PCE (%)
Pure $\text{SnO}_2$	$1.07 \pm 0.007$	$22.57 \pm 0.110$	$67.4 \pm 0.775$	$16.28 \pm 0.457$
1:0	$1.10 \pm 0.009$	$23.05 \pm 0.087$	$71.6 \pm 0.810$	$18.15 \pm 0.464$
20:2	$1.12 \pm 0.004$	$23.12 \pm 0.102$	$72.5 \pm 1.120$	$18.77 \pm 0.628$
20:3	$1.14 \pm 0.010$	$23.11 \pm 0.090$	$76.0 \pm 0.705$	$20.02 \pm 0.413$
20:4	$1.14 \pm 0.005$	$23.09 \pm 0.127$	$75.4 \pm 0.812$	$19.85 \pm 0.483$
1:1	$1.13 \pm 0.008$	$22.33 \pm 0.116$	$71.9 \pm 1.073$	$18.14 \pm 0.612$

**Table S3** Photovoltaic parameters of  $\text{MAPbI}_3$  solar cells with PEG-20000 at different substrates obtain in the reverse scan direction.

Devices	$V_{OC}$ (V)	$J_{SC}$ ( $\text{mA cm}^{-2}$ )	FF (%)	PCE (%)
Pure $\text{SnO}_2$	$1.07 \pm 0.007$	$22.57 \pm 0.110$	$67.4 \pm 0.775$	$16.28 \pm 0.457$
1:0	$1.10 \pm 0.009$	$23.05 \pm 0.087$	$71.6 \pm 0.810$	$18.15 \pm 0.464$
20:2	$1.12 \pm 0.010$	$23.12 \pm 0.092$	$73.0 \pm 0.857$	$18.90 \pm 0.491$
20:3	$1.11 \pm 0.011$	$23.10 \pm 0.106$	$71.4 \pm 0.765$	$18.31 \pm 0.401$
20:4	$1.10 \pm 0.007$	$22.31 \pm 0.117$	$70.8 \pm 0.932$	$17.38 \pm 0.541$
1:1	$1.10 \pm 0.012$	$21.96 \pm 0.097$	$66.7 \pm 0.840$	$16.11 \pm 0.430$

**Table S4** Photovoltaic parameters of Sn/PP-based devices based on substrate of different size

Devices	$V_{OC}$ (V)	$J_{SC}$ (mA cm $^{-2}$ )	FF (%)	PCE (%)
2.5 x 2.5 cm	1.11±0.006	22.83±0.077	72.5±0.681	18.37±0.232
3 x 3 cm	1.09±0.008	22.54±0.082	65.8±0.830	16.17±0.410
4 x 4 cm	1.08±0.011	22.30±0.101	52.8±1.132	12.72±0.554

The TRPL lifetimes are fitted with a biexponential function as following equation:

$$f(t) = A_1 \times e^{\frac{-t}{\tau_1}} + A_2 \times e^{\frac{-t}{\tau_2}}. \quad (\text{S1})$$

And the average TRPL lifetimes ( $\tau_{ave.}$ ) is calculated by the equation,

$$\tau_{ave} = \frac{A_1 \tau_1^2 + A_2 \tau_2^2}{A_1 \tau_1 + A_2 \tau_2}. \quad (\text{S2})$$