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Electronic Supplementary Information

Interface Modification with PCBM Intermediate Layers for Planar Formamidinium Perovskite Solar Cells

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Tables

Table S1. The photovoltaic parameters of the planar formamidinium perovskite solar cells without and with different PCBM intermediate layers.

Solar cell	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF	PCE (%)
w/o PCBM	1.08	12.3	0.497	6.6
PCBM10	1.03	16.7	0.603	10.4
PCBM20	1.06	19.7	0.599	12.5
PCBM30	1.05	22.7	0.653	15.5
PCBM40	1.05	18.1	0.642	12.2

Table S2. The extracted parameters from impedance data by fitting with equivalent circuit.

Solar cell	R_{ct} (Ω cm^2)	R_{rec} (Ω cm^2)
w/o PCBM	3.7	40.3
PCBM10	22.0	631.7
PCBM20	29.6	839.2
PCBM30	40.0	1236.3
PCBM40	706.4	1215.4

Table S3. Parameters for planar junction device with PCBM30 intermediate layer and conventional device with mesoporous TiO_2 layer under both forward and reverse scans.

Solar cell	Scan direction	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF	PCE (%)
With PCBM30	Reverse	1.04	22.56	0.691	16.23
	Forward	1.04	22.64	0.687	16.20
With mesoporous	Reverse	1.02	22.32	0.661	15.08
	Forward	0.928	22.38	0.519	10.78

Figures

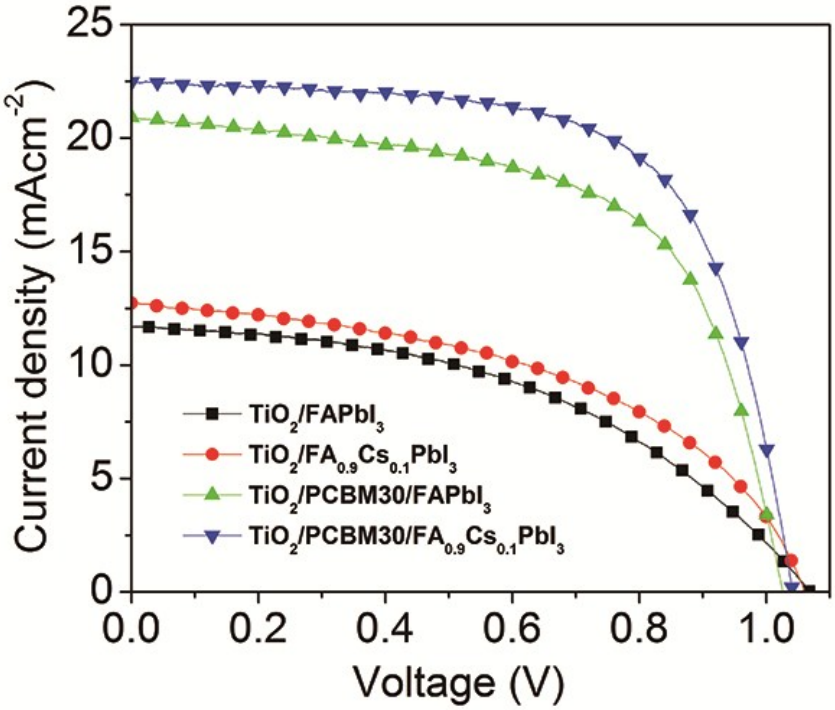

Figure S1. J-V curves of devices without and with PCBM30 intermediate layer. The planar devices are fabricated with both pure $FAPbI_3$ layers and 10 at% CsI doped $FAPbI_3$ layers as light harvesters. It indicates that CsI doping can improve the performance of planar devices. And it is also noted that PCBM30 intermediate layers have similar effect on the performance promotion for devices with both undoped and CsI doped $FAPbI_3$ layers as light harvesters.

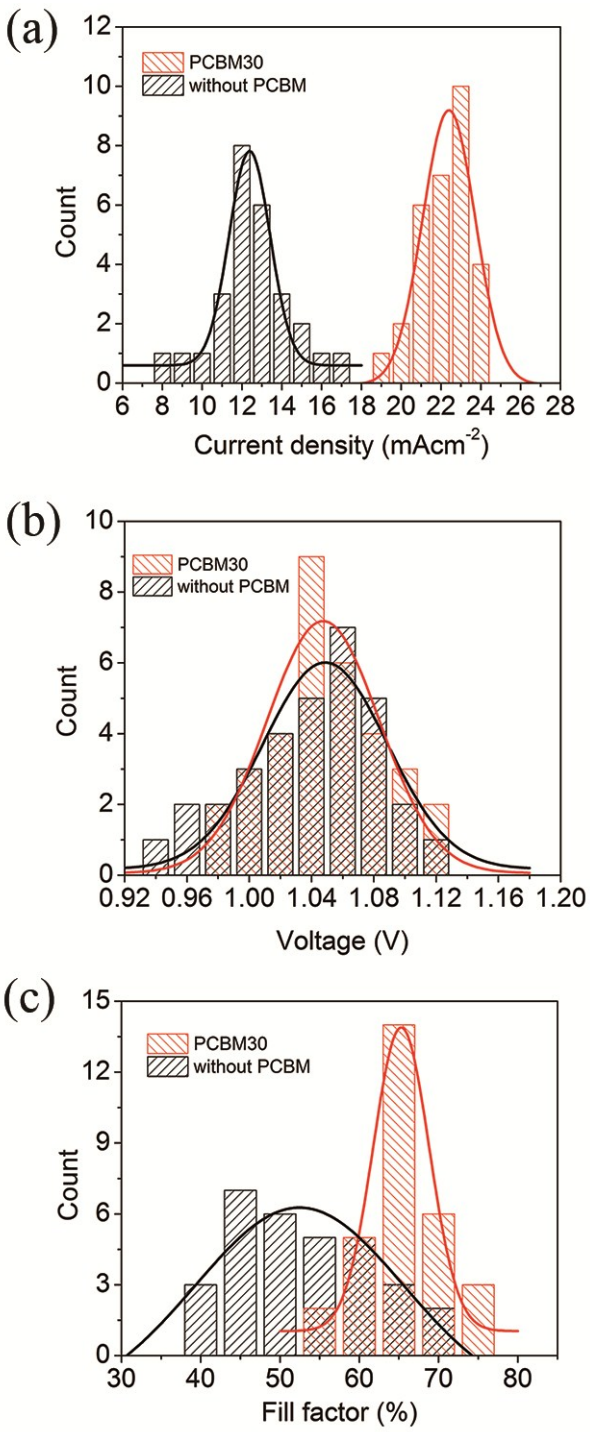

Figure S2. Statistics of J_{SC}, V_{OC}, and FF for the devices without and with PCBM30 intermediate layers.

It is noted that devices with and without PCBM30 intermediate layers have similar V_{OC} in Figure S2b. By adding PCBM30 intermediate layers, the large perovskite grains of light harvester layers can improve the transport/recombination process (figure 3), which is beneficial for achieving high V_{OC}. On the other hand, the PL and impedance measurements (figure 6 and 7) indicate that PCBM30 layer slightly retard the interface charge transfer process, which leads to a decrease of V_{OC}. The ultimate performance of devices is determined by both the transport/recombination process and interface charge transfer process. The similar V_{OC} in statistic data of both devices without/with PCBM30 layers can be attributed to the balanced between these two processes.

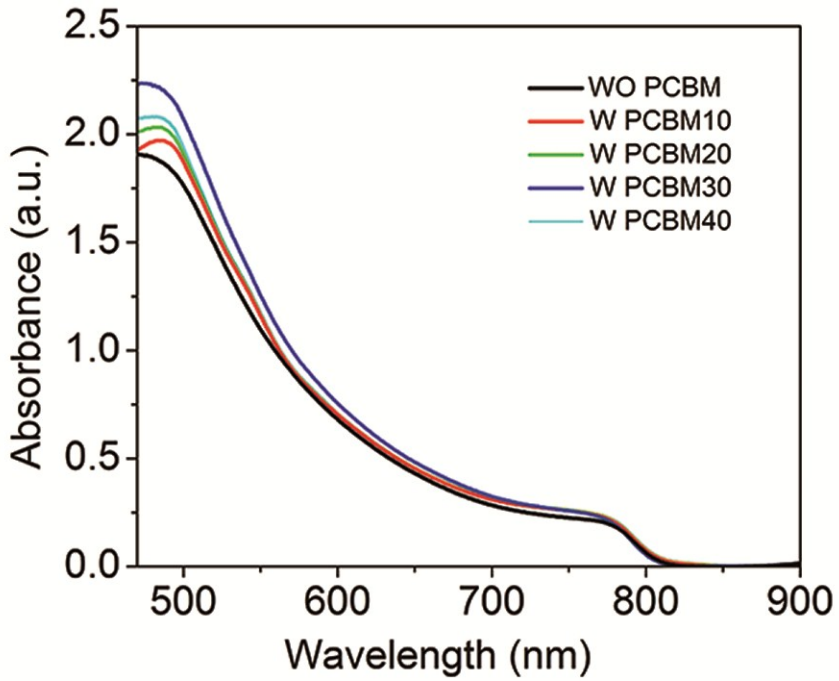

Figure S3. UV-vis absorption spectra of perovskite layers without and with different PCBM intermediate layers.

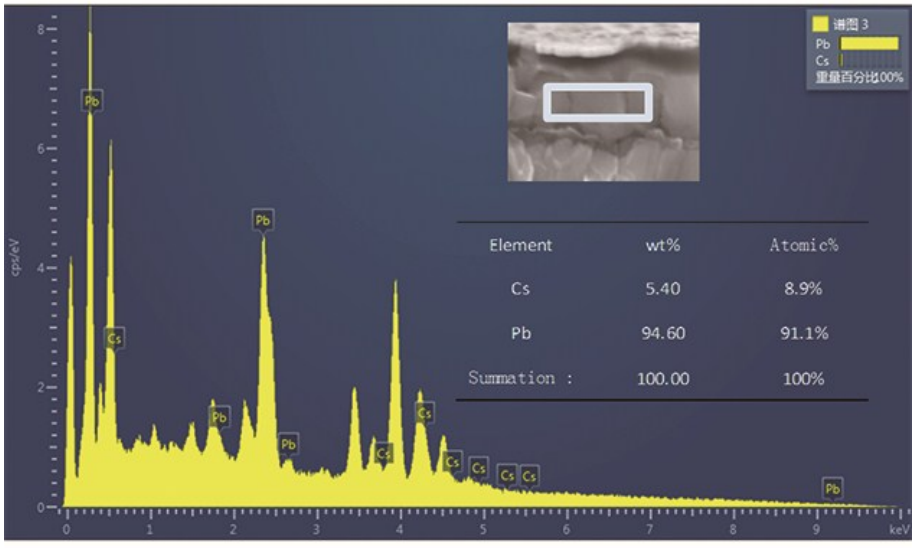

Figure S4. Energy dispersive x-ray spectrum (EDS) of CsI doped $FAPbI_3$ layer, and the ratio of Pb to Cs is shown in the table.

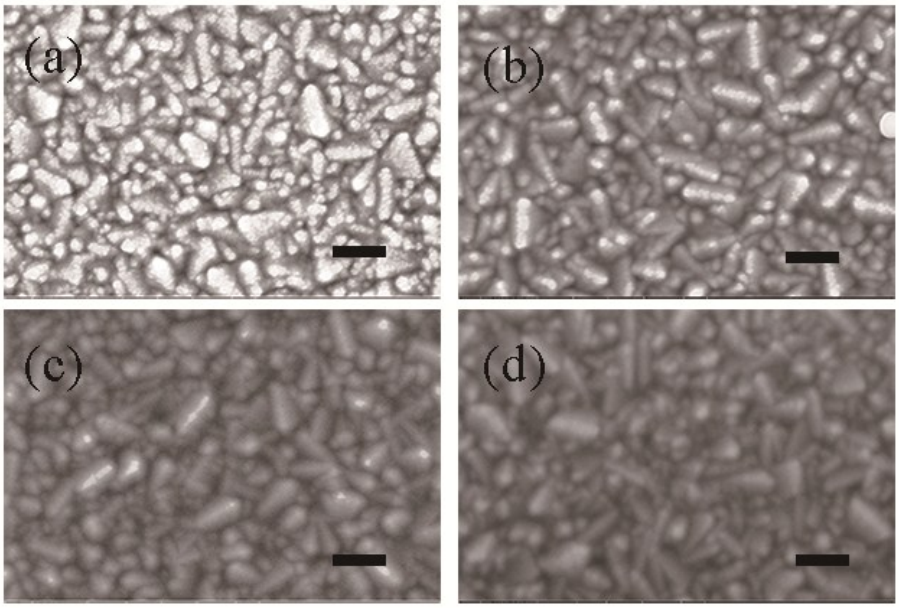

Figure S5. Top view SEM images of (a) PCBM10, (b) PCBM20, (c) PCBM30, and (d) PCBM40 intermediate layers on the TiO_2 coated FTO substrates. The scale bar is 500 nm.