Supporting Information

Iodine-doped ZnO Nanopillar Arrays for Planar Perovskite Solar Cells with High-Efficiency up to 18.24%

Yan-Zhen Zheng [a,b,*], Er-Fei Zhao [a], Fan-Li Meng [a], Xue-Sen Lai [a], Xue-Mei Dong [a], Jiao-Jiao Wu [a], and Xia Tao [a,*]

[a]State Key Laboratory of Organic-Inorganic Composites

Beijing University of Chemical Technology

15 Beisanhuan East Road, Beijing, 100029, P. R. China

*E-mail: zhengyz@mail.buct.edu.cn, taoxia@yahoo.com

[b]Research Center of the Ministry of Education for High Gravity Engineering & Technology, Beijing University of Chemical Technology

15 Beisanhuan East Road, Beijing, 100029, P. R. China

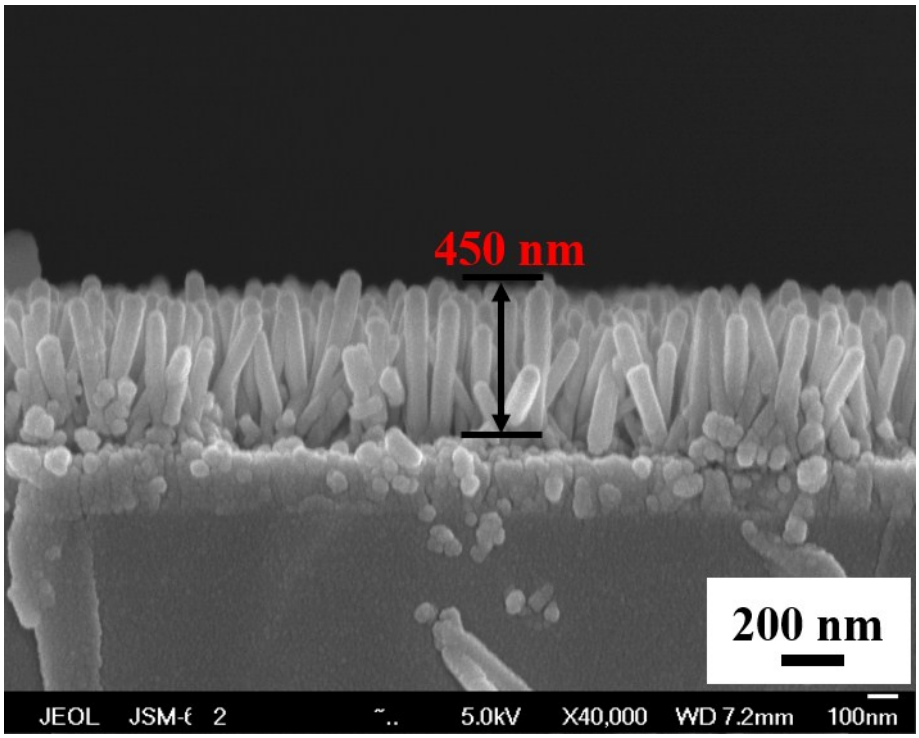

Fig. S1 Cross-sectional SEM image of ZnO NR film hydrothermally grown for 2 h.

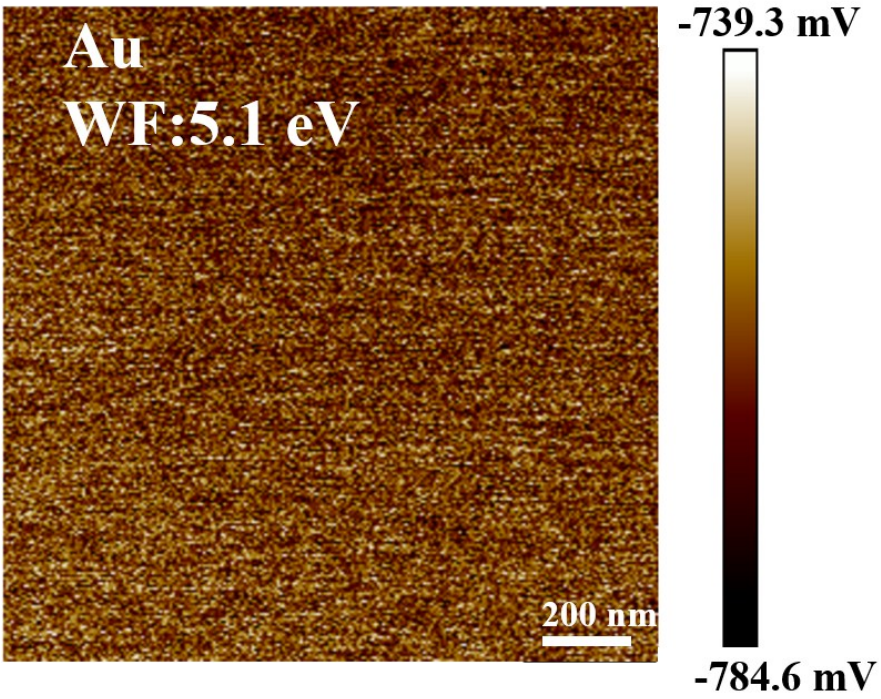

Fig. S2 Surface potential mapping of Au reference.

The work function of the ZnO NR and ZnO:I nanopillar films is measured by KPFM though probing the contact potential difference (CPD) between Antimony(n) doped Si tip and the samples. The WF_{sample} is defined as the following equation:

$$WF_{Sample} = WF_{tip} - eV_{CPD}$$

where e is the elementary charge of electron, WF_{tip} is the work function of Antimony(n) doped Si tip, and WF_{sample} is the work function of sample surface. The 1.5 × 1.5 μm^2 scan area is measured on Au, ZnO NR and ZnO:I nanopillar films, and the mean distribution of surface potential is employed as V_{CPD}. The constant work function of Au is 5.10 eV. The V_{CPD} between Antimony(n) doped Si tip and the Au, ZnO NR and ZnO:I nanopillar films are –762 mV, – 449 mV and – 368 mV, respectively, as shown in Fig. 4. Therefore, the work function of the ZnO NR and ZnO:I nanopillar are 4.79 and 4.71 eV, respectively.

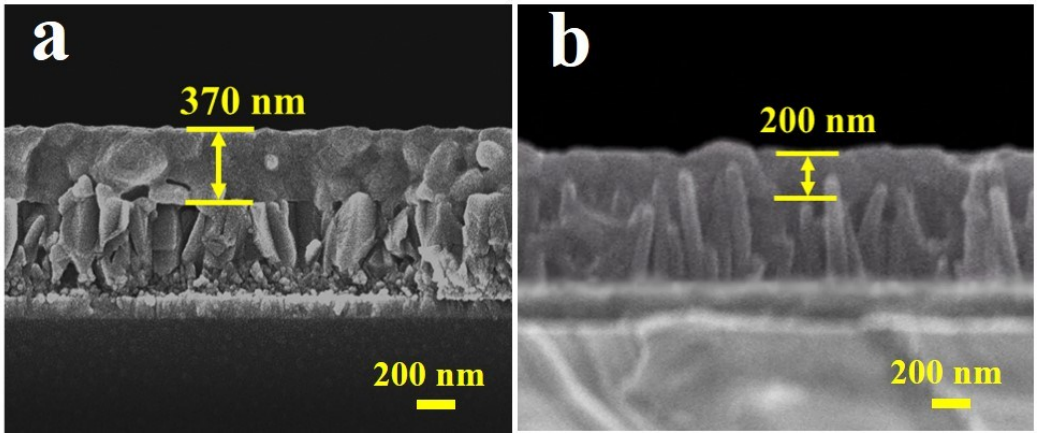

Fig. S3 Cross-sectional SEM images of perovskite deposition on the ZnO:I nanopillar (a) and ZnO NR (b) ETLs using one-step spin-coating process.

Table S1 Comprehensive comparison of 1D ETL structure, photovoltaic performance, perovskite processing method together with perovskite coverage between our work and other reported 1D ETL based PSCs .

1D ETL	Length (nm)	Diameter (nm)	PCE (%)	Perovskite processing method	Perovskite coverage	Ref.
ZnO:I nanopillar	450	~169	18.2	One-step	Complete	Our work
N:ZnO NRs	1071	~35	16.12	Two-step	Complete	14
ZnO NRs	1000	~80	11.13	Two-step	Incomplete	15
ZnO NRs	600	~60	14.35	Two-step	Complete	16
ZnO NRs	600	~50	5	One-step	Incomplete	17
TiO_2 NRs	560	~80	9.4	One-step	Incomplete	18

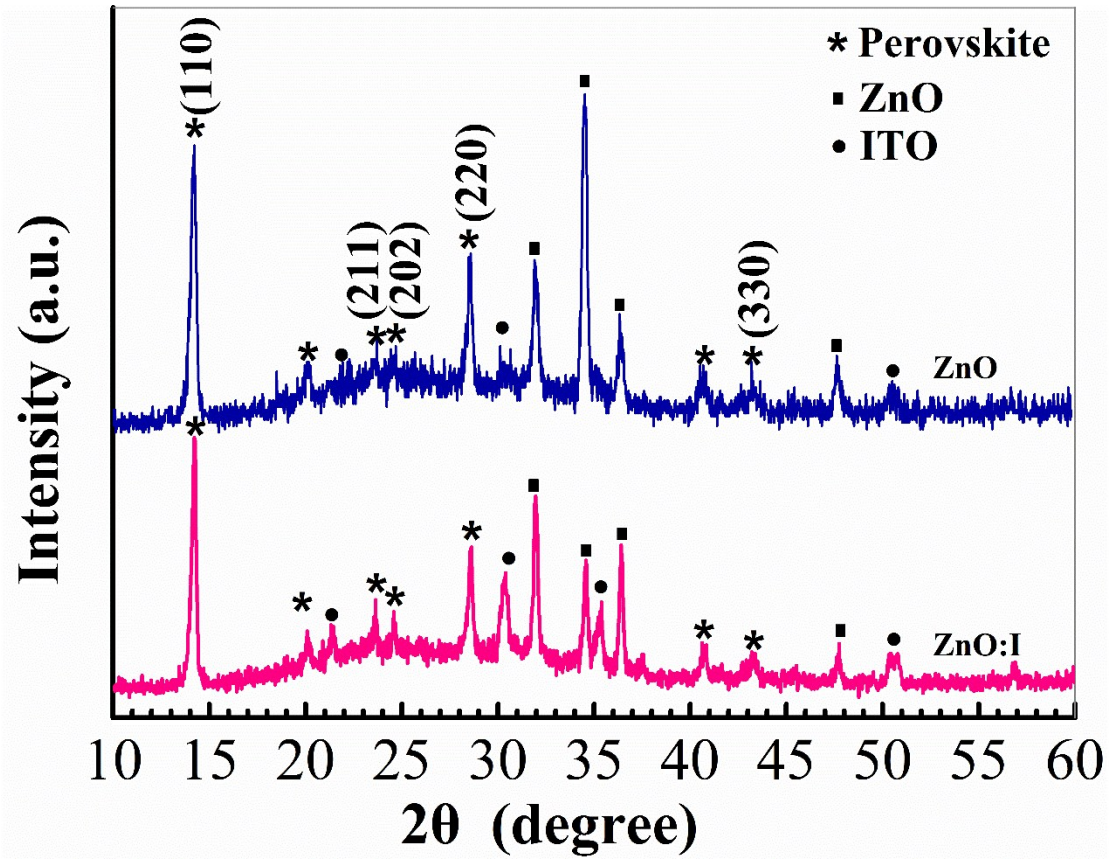

Fig. S4 XRD patterns of $CH_3NH_3PbI_3$ films deposited on ZnO NR ETL/ITO, and ZnO:I nanopillar ETL/ITO substrates, respectively.

Table S2 Photovoltaic parameters of a batch of 30 devices with ZnO NR as ETLs measured under AM 1.5G illumination at 100 mW cm^{-2} using reverse scan direction with a scan rate of 0.2 V s^{-1}.

Cell	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
1	1.07	18.04	55.89	10.79
2	1.03	15.76	53.46	8.68
3	1.07	17.16	55.82	10.25
4	1.08	17.95	55.42	10.74
5	1.05	17.79	55.67	10.40
6	1.05	16.06	53.21	8.97
7	1.06	17.94	55.56	10.57
8	1.01	16.45	52.02	8.64
9	1.04	17.31	53.00	9.54
10	1.02	17.54	54.78	9.80
11	1.00	16.4	51.01	8.37
12	1.09	17.21	56.14	10.53
13	1.05	17.97	55.14	10.40
14	1.02	17.86	54.71	9.97
15	1.00	16.47	50.15	8.26
16	1.02	16.06	54.95	9.00
17	1.05	17.86	55.65	10.44
18	1.04	17.03	55.06	9.75
19	1.03	17.53	54.51	9.84
20	1.02	16.82	54.11	9.28
21	1.07	17.61	55.57	10.47
22	1.02	16.27	53.13	8.82
23	1.03	17.22	55.38	9.82
24	1.05	18.02	54.31	10.28
25	1.05	17.80	55.74	10.42
26	1.04	17.64	54.68	10.03
27	1.02	17.10	55.41	9.66
28	1.01	16.46	52.26	8.69
29	1.03	16.83	54.10	9.38
30	1.02	17.98	55.01	10.09
Average	1.04±0.02	17.21±0.69	54.40±1.51	9.73±0.75

Table S3 Photovoltaic parameters of a batch of 30 devices with ZnO:I nanopillar as ETLs measured under AM 1.5G illumination at 100 mW cm^{-2} using reverse scan direction with a scan rate of 0.2 V s^{-1}.

Cell	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
1	1.13	22.42	71.99	18.24
2	1.14	22.11	67.01	16.89
3	1.13	21.00	71.33	16.93
4	1.12	22.17	69.95	17.37
5	1.12	22.18	71.24	17.70
6	1.10	21.37	70.56	16.59
7	1.11	21.48	71.23	16.98
8	1.10	21.53	70.75	16.76
9	1.08	22.15	71.16	17.02
10	1.09	21.97	68.03	16.29
11	1.08	22.88	71.75	17.73
12	1.11	21.99	71.36	17.42
13	1.09	22.02	68.53	16.45
14	1.09	22.07	69.42	16.70
15	1.13	21.47	71.36	17.31
16	1.14	21.63	69.76	17.20
17	1.14	21.61	67.83	16.71
18	1.07	22.00	68.87	16.21
19	1.10	21.23	72.37	16.90
20	1.12	22.21	70.12	17.44
21	1.12	22.37	71.89	18.01
22	1.08	22.00	70.38	16.72
23	1.09	21.55	69.05	16.22
24	1.13	21.6	72.16	17.61
25	1.14	21.71	70.38	17.42
26	1.13	21.51	69.85	16.98
27	1.12	21.34	70.72	16.90
28	1.13	22.07	67.48	16.83
29	1.11	21.37	70.46	16.71
30	1.12	21.91	69.64	17.09
Average	1.11±0.02	21.83±0.41	70.22±1.44	17.04±0.50

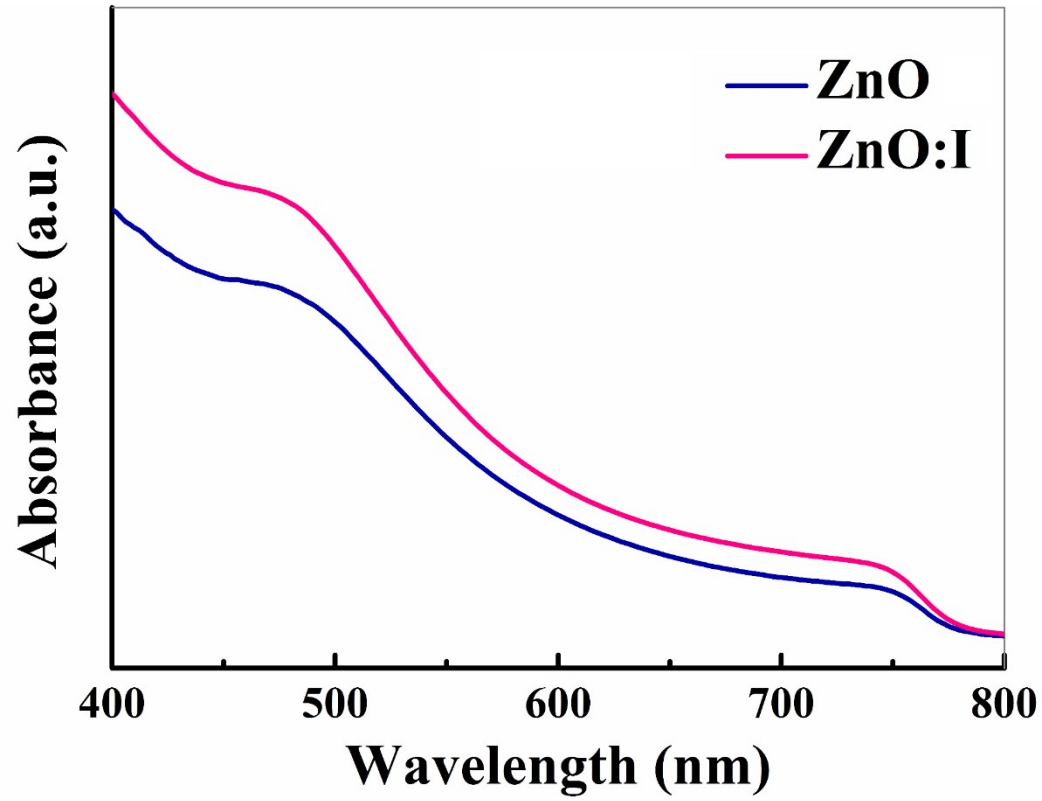

Fig. S5 UV-vis absorption spectra of $CH_3NH_3PbI_3$ films deposited on ZnO NR ETL/ITO, and ZnO:I nanopillar ETL/ITO substrates, respectively.

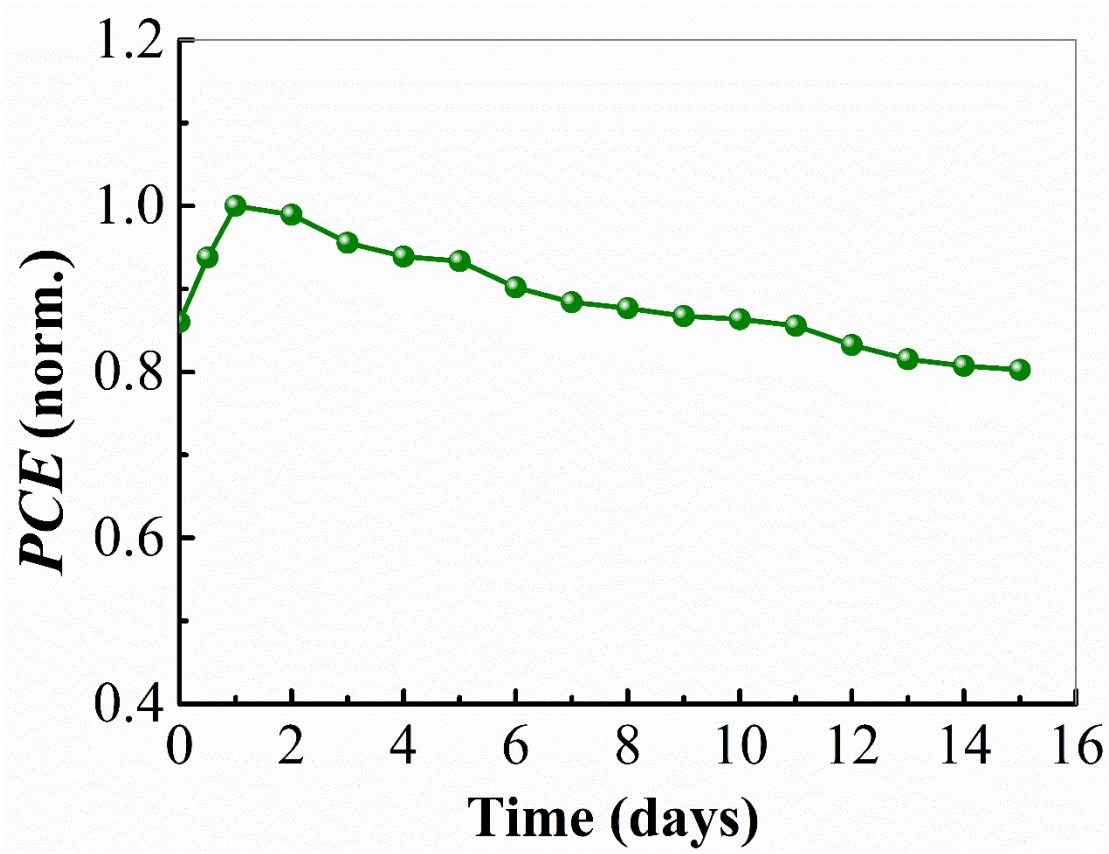

Fig. S6 Long term stability testing results for the unsealed PSC device based on ZnO:I nanopillar ETL.