Supporting Information

Toward Highly Reproducible, Efficient and Stable Perovskite Solar Cells via Interface Engineering with CoO Nanoplates

*Yanfei Dou, Deng Wang, Guodong Li, Yinsheng Liao, Weihai Sun, Jihuai Wu, Zhang Lan**

Engineering Research Center of Environment-Friendly Functional Materials, Ministry of Education; Fujian Key Laboratory of Photoelectric Functional Materials; Institute of Materials Physical Chemistry, College of Materials Science & Engineering, Huaqiao University, Xiamen 361021, China.

Tel.: +86 592 6162225; fax: +86 595 22693999.

E-mail address: lanzhang@hqu.edu.cn

Table S1. Photovoltaic parameters of the planar PSCs with CoO nanoplates modified layers from 3, 5 and 8 mg mL^{-1} CoO nanoplates solutions and the control one without CoO nanoplates modified layer (0 mg mL^{-1}), corresponding to the J-V curves shown in Figure 5a.

Conc./mg mL^{-1}	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
0	1.110	22.30	74.07	18.50
3	1.151	22.85	74.67	19.63
5	1.181	23.19	75.68	20.70
8	1.142	22.70	75.07	19.48

Table S2. Photovoltaic parameters of the optimized CoO nanoplates modified device (5 mg mL^{-1}) and the control one measured by forward and reverse scans, corresponding to the J-V curves shown in Figure 5b.

PSC		V_{OC}/V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
With CoO	Reverse	1.110	22.58	74.69	18.75
	Forward	1.071	22.42	73.40	17.65
	Average	1.090	22.50	74.05	18.20
W/O CoO	Reverse	1.191	23.24	75.00	20.72
	Forward	1.170	22.97	74.84	20.10
	Average	1.180	23.11	74.92	20.41

Table S3. Photovoltaic parameters of 20 optimized CoO nanoplates modified devices measured by reverse scan, corresponding to the data shown in Figure 5d.

PSC with CoO by reverse scan	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	1.173	23.71	73.61	20.47
2	1.168	22.95	75.82	20.32
3	1.175	23.29	74.19	20.30
4	1.169	22.94	75.64	20.28
5	1.172	23.26	74.26	20.25
6	1.165	22.90	75.74	20.21
7	1.167	22.91	75.43	20.17
8	1.165	22.91	75.41	20.13
9	1.166	22.82	75.36	20.04
10	1.164	22.89	75.15	20.02
11	1.184	22.87	73.66	19.94
12	1.166	22.97	75.85	20.31
13	1.166	22.94	75.56	20.20
14	1.183	22.83	74.38	20.09
15	1.178	23.34	74.25	20.42
16	1.183	22.84	74.17	20.05
17	1.169	22.97	74.84	20.10
18	1.166	22.91	75.65	20.20
19	1.181	23.32	73.61	20.26
20	1.184	22.86	73.93	20.01

Table S4. Photovoltaic parameters of 20 optimized CoO nanoplates modified devices measured by forward scan, corresponding to the data shown in Figure 5d.

PSC with CoO by forward scan	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	1.156	22.93	73.35	19.45
2	1.156	22.91	73.34	19.43
3	1.165	22.74	73.26	19.40
4	1.158	22.90	72.90	19.34
5	1.156	22.89	75.25	19.91
6	1.158	22.87	74.85	19.83
7	1.167	22.81	74.43	19.81
8	1.153	22.86	75.07	19.79
9	1.166	22.81	74.42	19.78
10	1.171	22.85	73.60	19.68
11	1.175	22.94	72.87	19.65
12	1.174	22.94	72.93	19.65
13	1.172	22.85	73.25	19.62
14	1.168	22.84	73.50	19.60
15	1.168	22.82	73.49	19.58
16	1.175	22.94	72.36	19.51
17	1.176	22.42	73.78	19.45
18	1.157	23.23	72.18	19.39
19	1.165	22.73	73.22	19.39
20	1.158	23.12	72.33	19.36

Table S5. Photovoltaic parameters of 20 control devices measured by reverse scan, corresponding to the data shown in Figure 5d.

PSC without CoO by reverse scan	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	1.142	22.83	74.46	19.41
2	1.139	22.74	71.75	18.58
3	1.137	22.69	72.71	18.76
4	1.136	22.70	73.61	18.99
5	1.138	22.69	73.22	18.90
6	1.137	22.70	73.80	19.04
7	1.131	22.96	72.69	18.88
8	1.131	22.97	74.10	19.25
9	1.129	22.97	74.13	19.23
10	1.127	22.94	73.99	19.13
11	1.127	23.05	73.55	19.11
12	1.128	23.13	73.32	19.12
13	1.126	23.06	73.35	19.04
14	1.126	23.05	73.21	19.00
15	1.131	23.04	72.38	18.86
16	1.153	22.49	74.12	19.22
17	1.152	22.45	75.14	19.43
18	1.151	22.46	75.01	19.39
19	1.149	22.44	75.03	19.34
20	1.139	22.20	73.39	18.56

Table S6. Photovoltaic parameters of 20 control devices measured by forward scan, corresponding to the data shown in Figure 5d.

PSC without CoO by farward scan	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	1.110	22.61	71.25	17.97
2	1.117	22.57	69.48	17.52
3	1.128	22.11	70.17	17.50
4	1.116	23.03	66.82	17.17
5	1.113	23.01	66.61	17.06
6	1.111	22.17	72.30	17.82
7	1.123	22.70	70.59	17.99
8	1.120	22.66	70.08	17.78
9	1.115	22.51	70.81	17.76
10	1.114	22.54	70.67	17.74
11	1.112	22.52	69.81	17.49
12	1.105	22.57	68.97	17.21
13	1.106	22.58	69.03	17.25
14	1.106	22.55	69.15	17.25
15	1.105	22.55	68.93	17.17
16	1.095	22.81	69.27	17.30
17	1.091	22.80	68.62	17.07
18	1.113	22.05	72.24	17.72
19	1.113	22.05	71.25	17.48
20	1.105	22.06	73.26	17.87

Table S7. The TRPL key parameters [fast extraction time (τ_1), slow radiative recombination lifetime (τ_2), decay amplitudes (A_1 and A_2), and average TRPL decay time (τ_{avg})] of the perovskite, perovskite/Spiro-OMeTAD and perovskite/CoO nanoplates/Spiro-OMeTAD films.

Samples	τ_{avg} /ns	τ_1 /ns	τ_2 /ns	A_1/%	A_2/%
Perovskite	29.78	11.19	60.98	62.66	37.34
Perovskite/Spiro	5.05	3.40	17.73	88.49	11.51
Perovskite/CoO/Spiro	3.87	2.35	13.56	86.42	13.58

Table S8. Light intensity dependence of the photovoltaic parameters of the optimized CoO nanoplates modified device measured by reverse scan, corresponding to the data shown in Figure 6d and e.

Light intensity	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	0.961	0.30	70.62	0.20
10	1.047	2.18	75.35	1.72
20	1.078	4.73	75.76	3.86
30	1.092	6.52	75.81	5.39
40	1.103	8.77	75.95	7.35
50	1.113	11.08	75.72	9.34
60	1.121	13.42	75.87	11.41
70	1.124	15.63	75.47	13.26
80	1.131	18.20	75.49	15.53
90	1.131	20.35	75.05	17.27
100	1.141	22.88	73.27	19.13

Table S9. Light intensity dependence of the photovoltaic parameters of the control device measured by reverse scan, corresponding to the data shown in Figure 6d and e.

Light intensity	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	0.924	0.29	69.57	0.18
10	0.978	2.11	57.29	1.18
20	1.021	4.22	64.28	2.77
30	1.024	6.40	59.66	3.91
40	1.030	8.57	62.71	5.54
50	1.050	10.76	65.89	7.44
60	1.080	13.02	71.57	10.06
70	1.089	15.28	73.26	12.18
80	1.093	17.54	73.63	14.11
90	1.098	20.30	73.38	16.35
100	1.100	22.55	72.95	18.10

Table S10. Photovoltaic parameters of the optimized CoO nanoplates modified device stored in ambient air for different time and measured by reverse scan, corresponding to the data shown in Figure 7.

Storage time/days	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
0	1.185	23.21	75.66	20.81
5	1.171	22.85	73.60	19.68
10	1.169	22.28	72.83	18.97
15	1.164	22.25	71.63	18.55
20	1.147	22.12	70.76	17.94
25	1.144	22.12	69.30	17.54
30	1.121	22.20	68.72	17.10

Table S11. Photovoltaic parameters of the control device stored in ambient air for different time and measured by reverse scan, corresponding to the data shown in Figure 7.

Storage time/days	V_{OC} /V	J_{SC}/mA cm^{-2}	FF/%	PCE/%
1	1.113	22.40	75.18	18.74
2	1.107	22.05	73.79	18.01
3	1.107	20.89	59.44	13.74
4	1.097	18.06	56.42	11.18
5	0.910	18.02	51.72	8.48
10	0.833	11.23	41.35	3.86

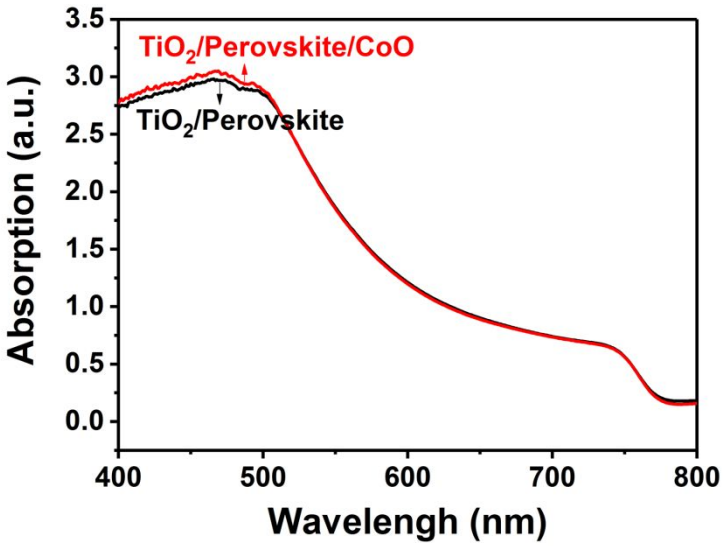

Figure S1. UV-Vis absorption spectra of the perovskite film and the one coated with CoO nanoplates atop on the TiO_2 ETLs.