Electronic Supplementary Information

Ru-doping in TiO_2 Electron Transport Layers of Planar Heterojunction Perovskite Solar cells for Enhanced Performance

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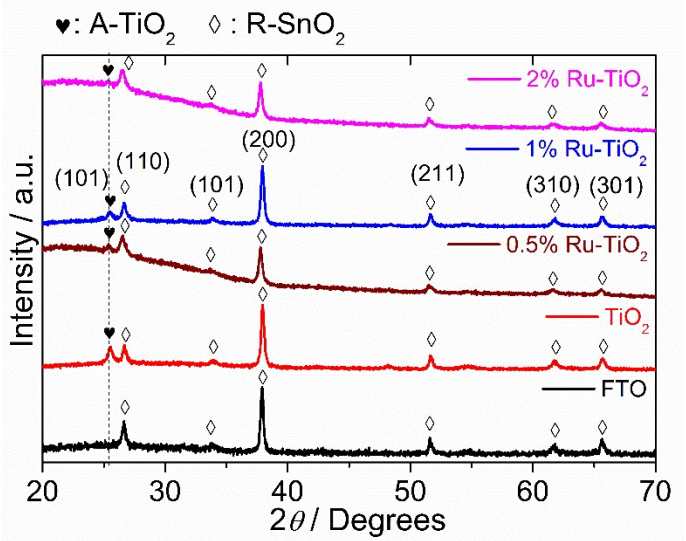

Figure S1 XRD patterns of the blank FTO substrate, pristine and Ru-doped TiO_2 ETLs with different Ru concentrations.

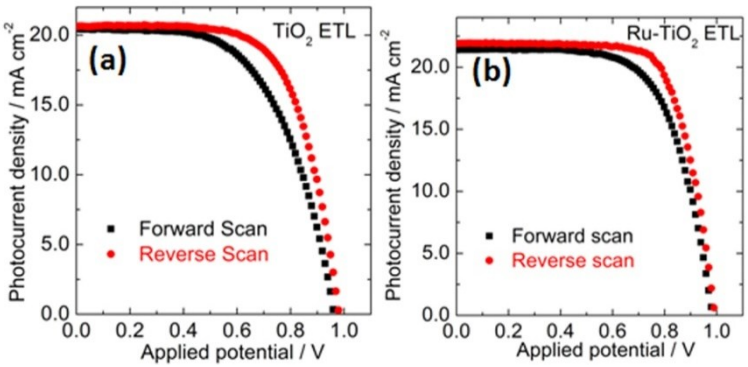

Figure S2 Photocurrent density-voltage (J-V) curves of perovskite solar cells with the pristine (a) and Ru doped TiO_2 electron transport layers (b) under AM 1.5G (100 mW cm^{-2}) at different scanning modes. Forward scan: from 0 V to open-circuit voltage; Reverse scan: from open-circuit voltage to 0 V.

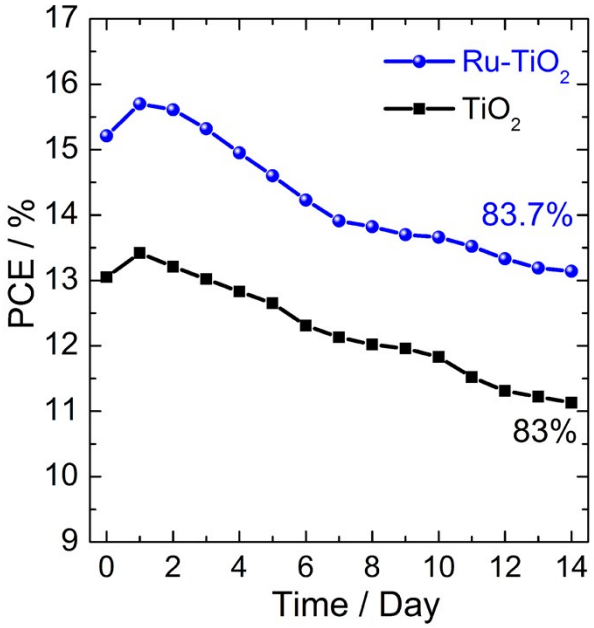

Figure S3 The variation of PCE of perovskite solar cells with the time. The devices were not packaged, and stored in a desiccator.

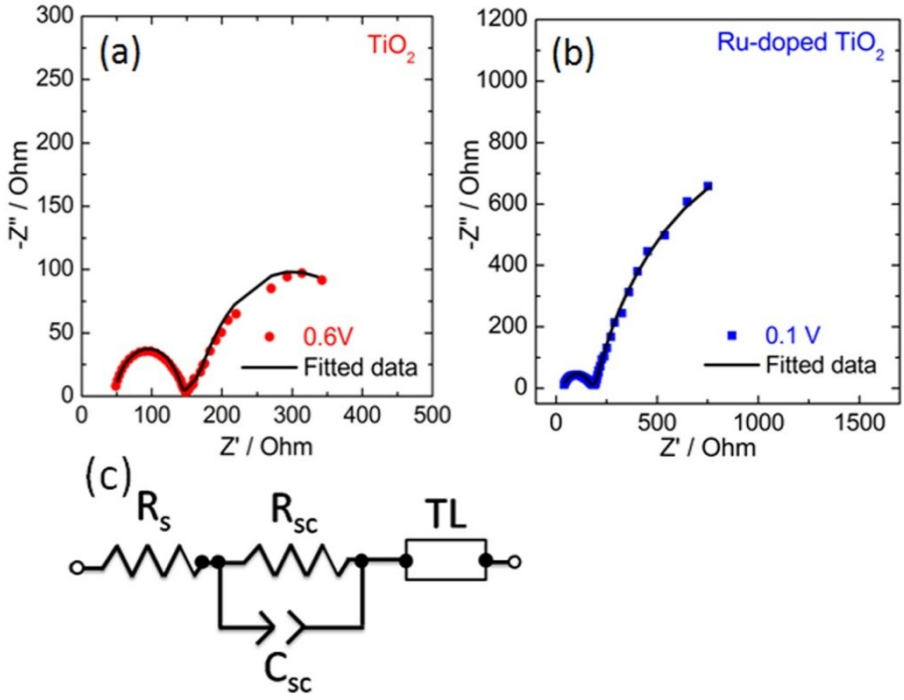

Figure S4 Typical Nyquist plots of planar heterojunction perovskite solar cells with (a) the pristine and (b) Ru doped TiO_2 ETLs measured under the light illumination at different forward biases. Discrete symbols represent the experimental results and solid lines are fitted data. (c) The equivalent circuit used for fitting in the study.

Table S1 Photocurrent density-voltage (J-V) parameters of the champion perovskite solar cells with the pristine TiO_2 electron transport layer (a) and Ru doped TiO_2 electron transport layer (b) at different scanning modes

Device	V_{oc} / V	J_{sc} / mA cm^{-2}	FF	PCE / %
TiO_2 (reverse)	0.980	20.66	0.663	13.42
TiO_2 (forward)	0.968	20.49	0.584	11.58
Ru-TiO_2 (reverse)	0.994	21.91	0.721	15.70
Ru-TiO_2 (forward)	0.978	21.87	0.631	13.50

V_{oc}: Open-circuit photovoltage, J_{sc}: Short-circuit photocurrent density, FF: Fill factor, PCE: Power conversion efficiency

Table S2 Summary of photovoltaic parameters of perovskite solar cells using the pristine or 1% Ru-doped TiO_2 ETL

Electron transport layer		V_{oc} / V	J_{sc} /mA cm^{-2}	FF	PCE / %
TiO_2	Champion	0.980	20.66	0.663	13.42
	Average	0.962	20.36	0.623	12.20
1% Ru-TiO_2	Champion	0.994	21.91	0.721	15.70
	Average	0.991	21.65	0.687	14.74

Table S3 Photovoltaic parameters of 30 perovskite solar cells with the pristine TiO_2 ETL

Device No.	V_{oc} / V	J_{sc} / mA cm^{-2}	FF	PCE / %
1	0.974	20.52	0.561	11.21
2	0.984	20.81	0.630	12.90
3	0.982	20.22	0.577	11.53
4	0.944	20.60	0.612	11.90
5	0.954	19.47	0.571	10.61
6	0.977	21.06	0.623	12.82
7	0.973	20.33	0.666	13.17
8	0.980	20.66	0.663	13.42
9	0.984	19.72	0.606	11.76
10	0.974	19.65	0.670	12.82
11	0.989	21.34	0.601	12.68
12	0.988	21.08	0.597	12.43
13	0.979	21.15	0.591	12.24
14	0.924	19.53	0.663	11.96
15	0.933	19.78	0.599	11.05
16	0.942	21.28	0.595	11.93
17	0.945	20.05	0.600	11.37
18	0.966	20.54	0.584	11.59
19	0.962	19.38	0.606	11.30
20	0.959	20.25	0.647	12.56
21	0.981	19.80	0.680	13.21
22	0.947	20.14	0.661	12.61
23	0.975	20.75	0.620	12.54
24	0.942	20.93	0.642	12.66
25	0.970	19.99	0.643	12.47
25	0.932	19.48	0.667	12.11
27	0.957	20.60	0.609	12.01
28	0.947	21.22	0.605	12.16
29	0.939	21.01	0.625	12.34
30	0.942	19.66	0.668	12.37

Table S4 Photovoltaic parameters of 30 perovskite solar cells with the Ru doped TiO_2 ETL

Device No.	V_{oc} / V	J_{sc} / mA cm^{-2}	FF	PCE / %
1	0.994	21.91	0.721	15.70
2	0.985	22.39	0.660	14.46
3	0.988	21.72	0.661	14.18
4	0.973	21.84	0.630	13.39
5	0.977	22.09	0.665	14.35
6	0.982	21.91	0.666	14.33
7	0.979	21.95	0.667	14.41
8	0.978	21.60	0.670	14.32
9	0.995	21.92	0.673	14.67
10	1.002	22.18	0.688	15.29
11	1.004	22.05	0.686	15.19
12	0.998	21.71	0.656	14.21
13	0.962	21.98	0.741	15.67
14	1.008	21.40	0.719	15.51
15	0.984	21.37	0.731	15.37
16	0.994	21.30	0.659	13.95
17	0.996	21.81	0.710	15.42
18	0.988	21.33	0.722	15.22
19	0.997	21.58	0.708	15.23
20	0.983	21.42	0.706	14.86
21	0.983	21.30	0.721	15.10
22	0.985	21.33	0.700	14.71
23	0.985	20.76	0.732	14.97
24	0.984	20.52	0.728	14.70
25	0.944	21.63	0.664	13.56
25	1.045	21.58	0.654	14.75
27	1.035	22.19	0.649	14.91
28	1.044	21.46	0.659	14.76
29	0.974	21.63	0.705	14.85
30	0.995	21.69	0.642	13.86