

Supporting Information

**Identifying the optimum thickness of electron transport layer for
highly efficient perovskite planar solar cells**

Hao Lu, Yulong Ma, Bangkai Gu, Wei Tian* and Liang Li*

*College of Physics, Optoelectronics and Energy, Collaborative Innovation Center of
Suzhou Nano Science and Technology, Jiangsu Key Laboratory of Thin Films,
Soochow University, Suzhou, 215006, P. R. China*

Email: wtian@suda.edu.cn, lli@suda.edu.cn

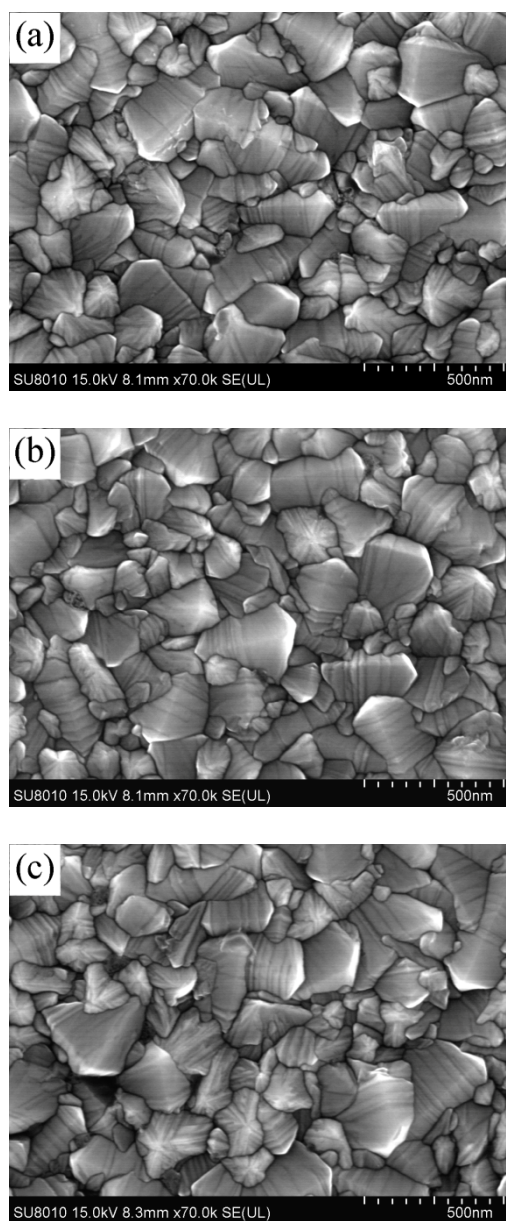


Fig. S1 SEM images of FTO substrates after (a) 5, (b) 10, and (c) 15 nm ALD-TiO₂ coating.

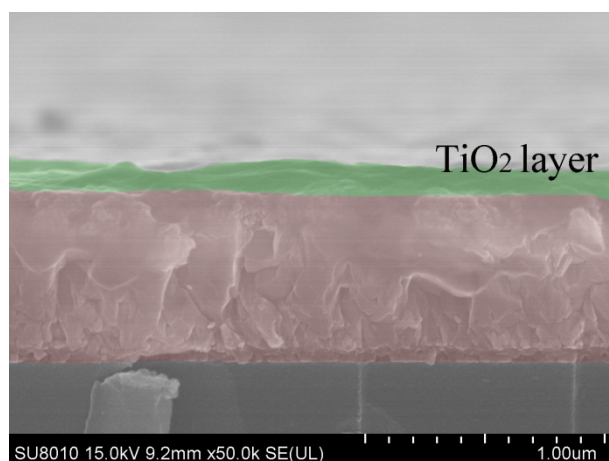


Fig. S2 Cross-sectional SEM image of FTO substrate with TiO₂ film deposited by spin-coating technique.

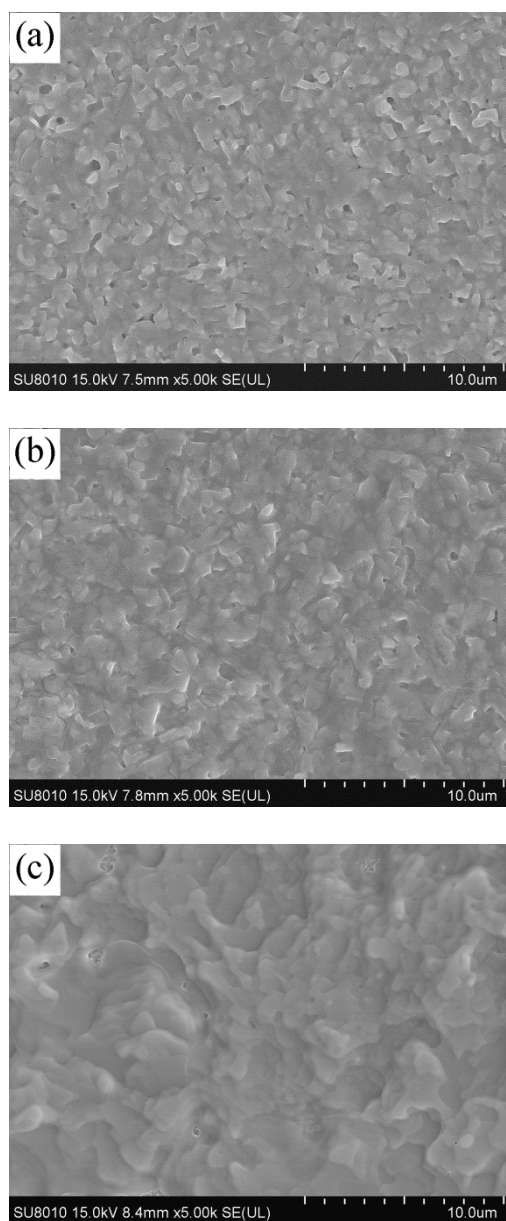


Fig. S3 SEM images of annealed perovskite layers on 10 nm ALD-TiO₂ films with different waiting time: (a) 5, (b) 10, and (c) 15 s.

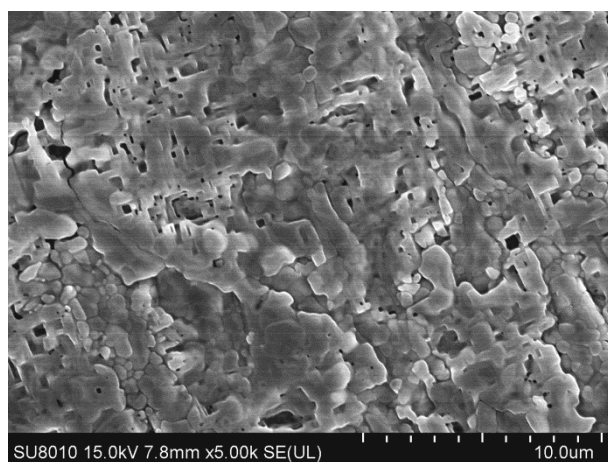


Fig. S4 SEM image of perovskite layer spin-coated on conventional TiO₂ film.

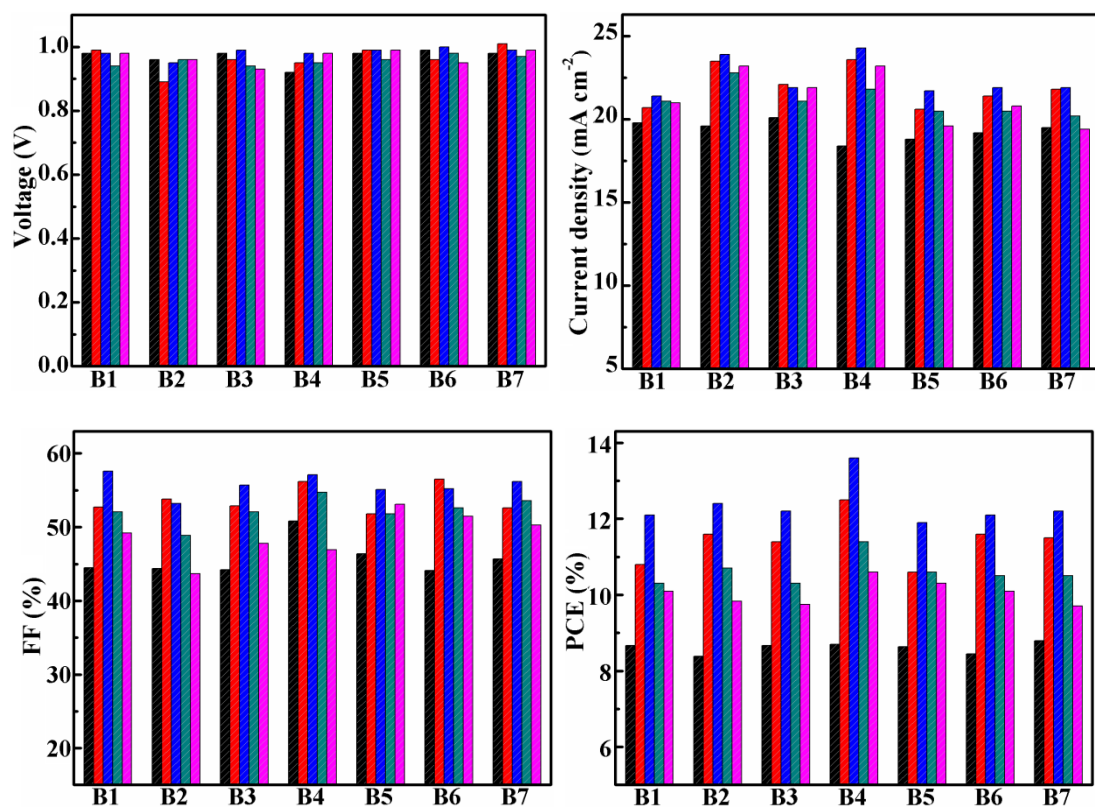


Fig. S5 The histogram plots of key parameters of as-fabricated seven batches (B1-B7) of solar cells. Note: Columns from black to magenta color represent devices fabricated using spin-coated TiO₂, and 5, 10, 15 and 20 nm ALD TiO₂.

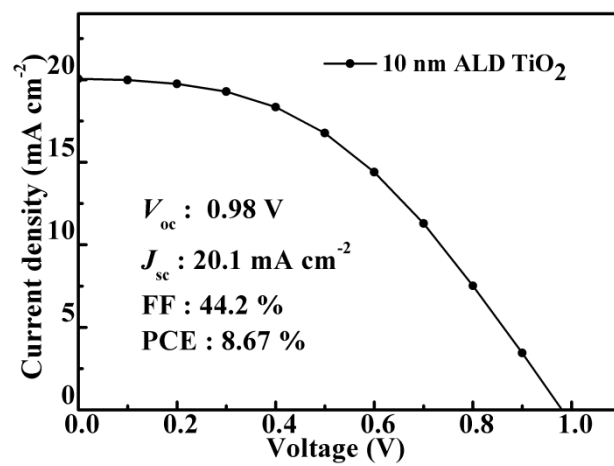


Fig. S6 J - V curve of a cell based on 10 nm ALD TiO₂ layer without annealing treatment and corresponding photovoltaic parameters.

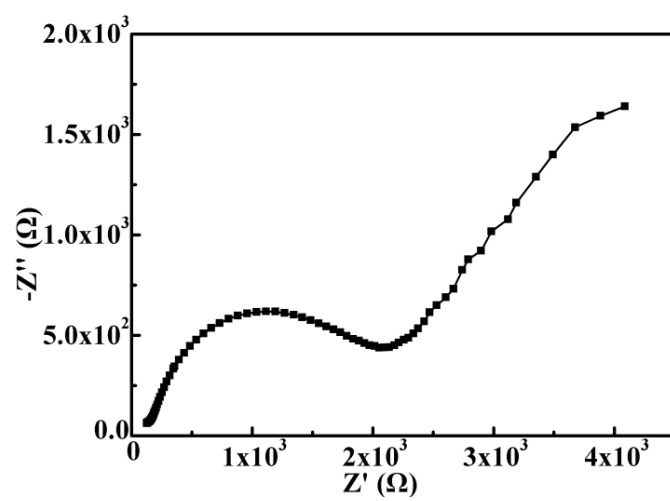


Fig. S7 Nyquist curve of an incomplete solar cell without a TiO_2 layer.

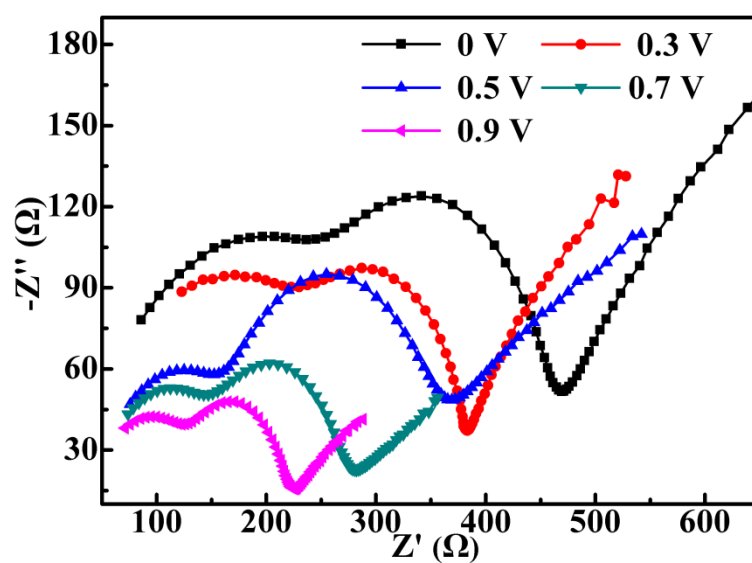


Fig. S8 Nyquist curves of the 10 nm ALD TiO₂ devices measured at different bias voltages (0, 0.3, 0.5, 0.7 and 0.9 V).

Sample	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
ALD-5 nm	0.96 ± 0.04	21.96 ± 1.22	53.79 ± 1.85	11.4 ± 0.62
ALD-10 nm	0.98 ± 0.02	22.13 ± 1.16	55.73 ± 1.45	12.6 ± 0.57
ALD-15 nm	0.96 ± 0.02	21.01 ± 1.06	52.44 ± 1.81	10.6 ± 0.39
ALD-20 nm	0.96 ± 0.02	21.43 ± 1.42	48.74 ± 2.87	10.1 ± 0.38
Spin-coating	0.97 ± 0.03	19.34 ± 0.59	45.73 ± 2.39	8.61 ± 0.15

Table S1 Summary of the average values of photovoltaic parameters of seven batches of solar cells based on different ALD TiO₂ thicknesses and traditional TiO₂ layer by spin-coating.

Sample	$R_s (\Omega)$	$R_{ct} (\Omega) = R_{ct1} + R_{ct2}$	$R_{rec} (\Omega)$
ALD-5 nm	6.86 ± 1.3	513.5 ± 29.54	1286.54 ± 84.2
	5		7
ALD-10 nm	11.2 ± 3.2	546.8 ± 23.47	969.04 ± 70.96
	7		
ALD-15 nm	20.7 ± 3.7	637.4 ± 39.01	1416.92 ± 82.0
	5		9
ALD-20 nm	28.9 ± 1.2	730.3 ± 17.29	1257.6 ± 112.0
	9		6
Spin-coating	14.4 ± 2.1	587.0 ± 14.62	2302.6 ± 152.5
	1		8

Table S2 Summary of the average values of EIS parameters of solar cells based on different ALD TiO₂ thicknesses and traditional TiO₂ layer by spin-coating.

Bending times	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
0	0.90	18.3	43.5	7.17
10	0.88	16.8	45.4	6.78
50	0.80	18.0	30.2	4.35

Table S3 Summary of the photovoltaic parameters of flexible devices without bending, and after 10 and 50 cycles of bending.