Supporting Information

Silicotungstate, a Potential Electron Transporting Layer for Low-Temperature Perovskite Solar Cells

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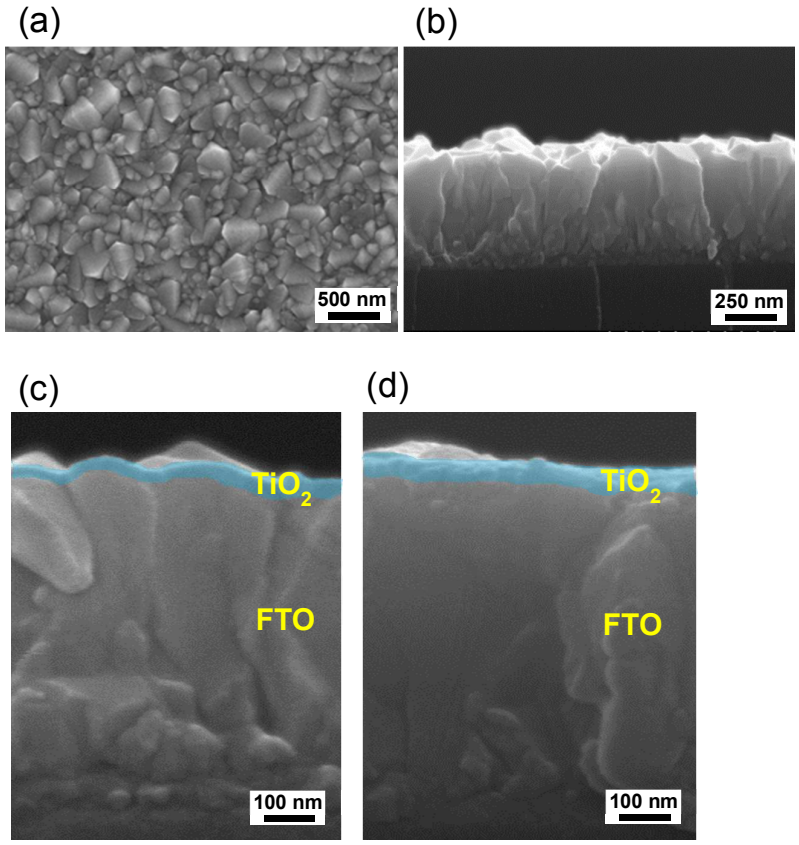


Figure S1. SEM images of the bare FTO glass (a and b) and cross-sectional SEM images for the TiO_2 layers heat-treated at 150°C (c) and 500°C (d).

TiO_2-150 was prepared by following procedure. 6.53 g titanium isopropoxide (Aldrich) and 1.65 mL triethanolamine were added to 21 mL ethanol, and stirred for 10 min. The mixture of 10 mL ethanol and 0.36 mL water was then added dropwise to obtain the Ti-sol stock solution. It was then diluted in ethanol to obtain 0.3 M Ti-sol solution. The prepared Ti-sol solution was spin-coated at 4,000 rpm on the FTO glass, followed by baking at 150°C for 1 h. The prepared film was inserted in 40 mM $TiCl_4$ aqueous solution, kept at 70°C, for 20 min. The film was then washed thoroughly by water and ethanol, followed by heat-treatment at 150°C for 1 h.

For the preparation of TiO_2-500, 0.15 M and 0.3 M Ti-sol solutions were prepared, respectively, by diluting TIPD [titanium (diisopropoxide) bis(2,4-pentanedionate), Aldrich] with isopropanol. On the FTO glass, initially 0.15 M Ti-sol was spin-coated at 4,000 rpm, followed by baking at 100°C for 5 min. Then, the film was prepared by two cycles of coating, each of which consists of spin-coating at 4,000 rpm with 0.3 M Ti-sol solution and baking at 100°C for 5 min. Finally, the prepared film was thermally treated at 500°C for 30 min.

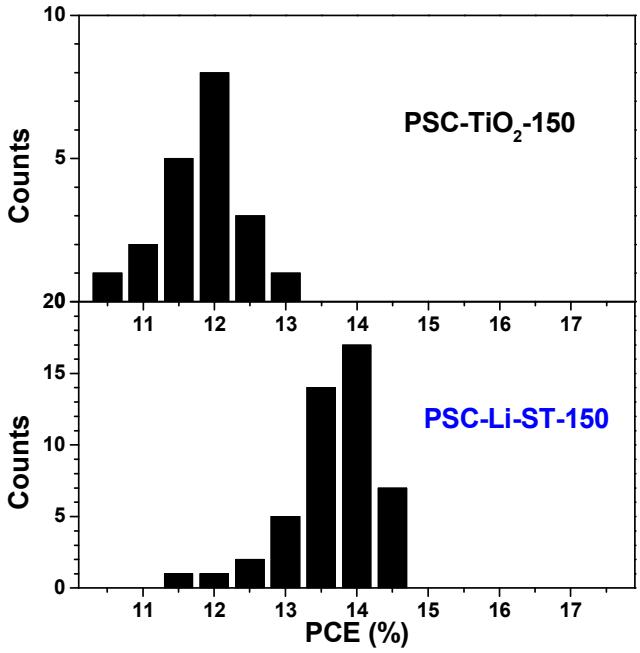
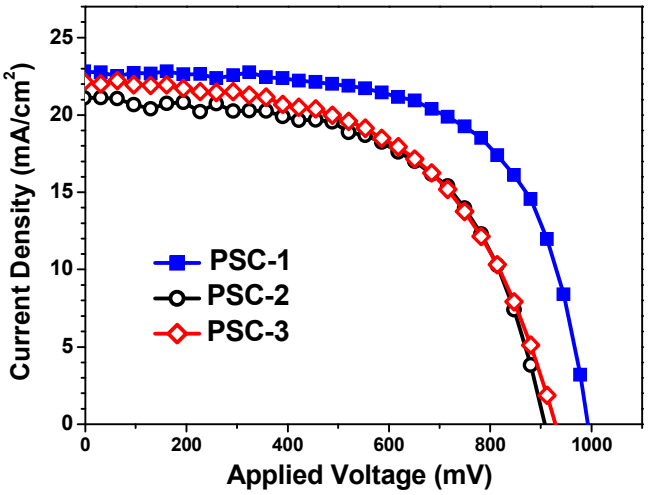
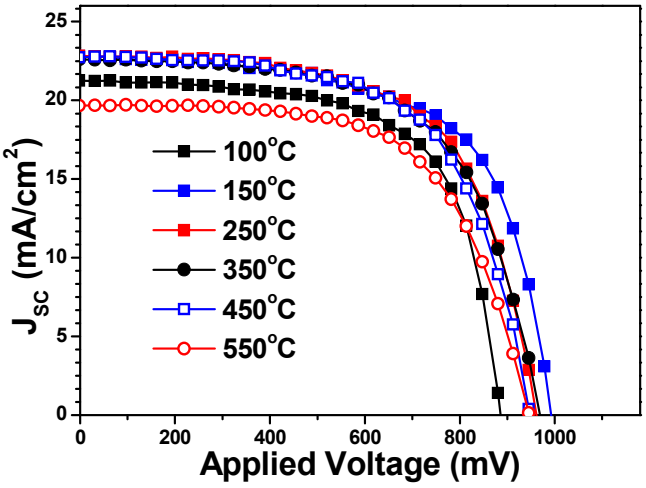


Figure S2. Normalized PCE distributions for the 20 devices of PSC-TiO_2-150 and 46 devices of PSC-Li-ST-150.



PSCs	V_{OC} (mV)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
PSC-1	992	22.75	62.98	14.21
PSC-2	904	21.05	59.87	11.39
PSC-3	961	22.11	56.34	11.97

Figure S3. *J-V* curves of the PSC devices employing the Li-ST layers prepared under various conditions. PSC-1 and 2 denotes the PSCs with and without introducing the L-lysine monolayer, respectively, while the Li-ST layer was composed of the buffer and the main layer prepared by two cycles of coating for the both samples. PSC-3 denotes the PSC employing the Li-ST layer prepared by two cycles of coating without introducing the buffer layer, while the L-lysine monolayer was introduced on the FTO surface. All the Li-ST layers were heat-treated at 150^{o}C.



Heat-treatment temperature for Li-ST (°C)	V_{OC} (mV)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
100	885	21.23	64.74	12.16
150	992	22.75	62.98	14.21
250	961	22.91	62.44	13.75
350	969	22.69	61.30	13.48
450	947	22.65	62.64	13.44
550	948	19.67	63.26	11.80

Figure S4. *J-V* curves of the PSC devices employing the Li-ST layers heat-treated at various temperatures. For all the devices, the fabricated Li-ST films are composed of the buffer and the main Li-ST layer prepared by two cycles of coating.

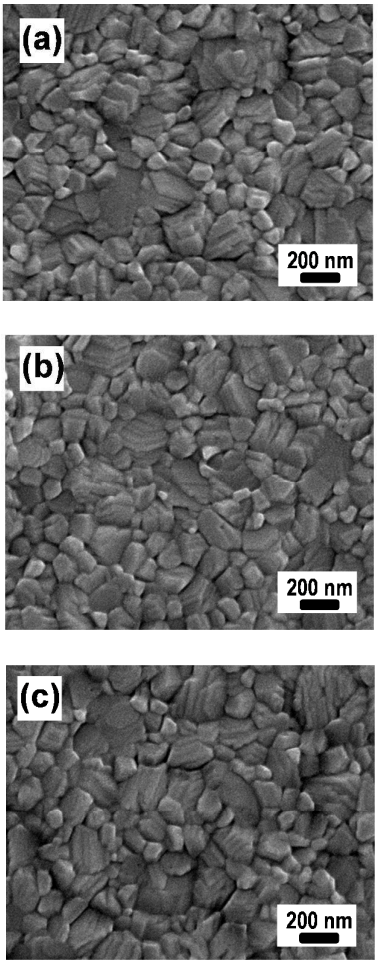
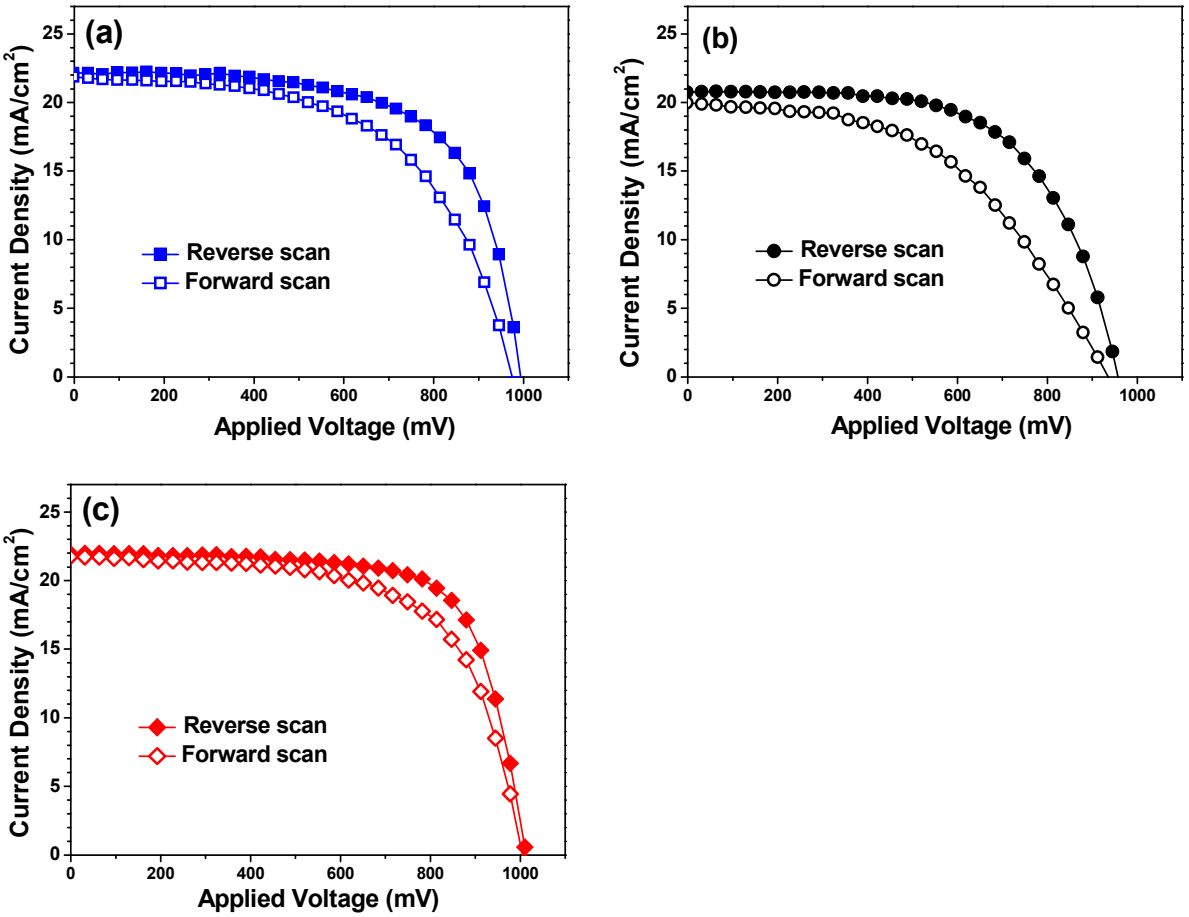


Figure S5. Plan-view SEM images of $CH_3NH_3PbI_3$ films prepared on the Li-ST-150 (a), TiO_2-150 (b) and TiO_2-500 (c) layers



PSCs/Scan		V_{OC} (mV)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
PSC-Li-ST-150	reverse	993	22.16	64.81	14.26
	forward	974	21.85	60.37	12.84
PSC-TiO_2-150	reverse	954	20.77	61.94	12.27
	forward	936	19.96	54.05	10.09
PSC-TiO_2-500	reverse	1013	21.98	72.83	16.22
	forward	1005	21.74	68.86	15.05

Figure S6. *J–V* curves of PSC-Li-ST-150 (a), PSC-TiO_2-150 (b) and PSC-TiO_2-500 (c) acquired by forward and reverse scans with a scan rate of 100 mVs^{-1}.