

Supporting information

ZnO/SnO₂ Double Electron Transport Layer Guides Improved Open Circuit Voltage for Highly Efficient CH₃NH₃PbI₃-based Planar Perovskite Solar Cells

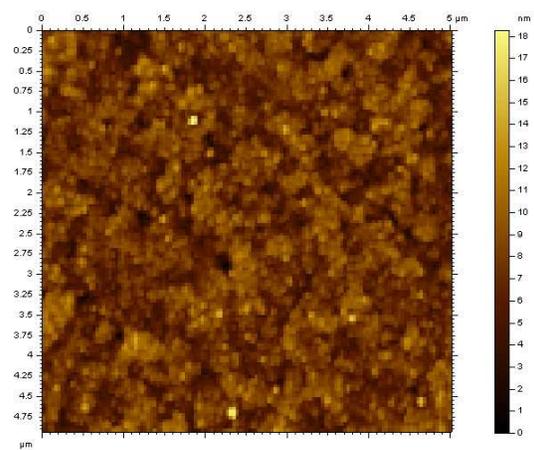
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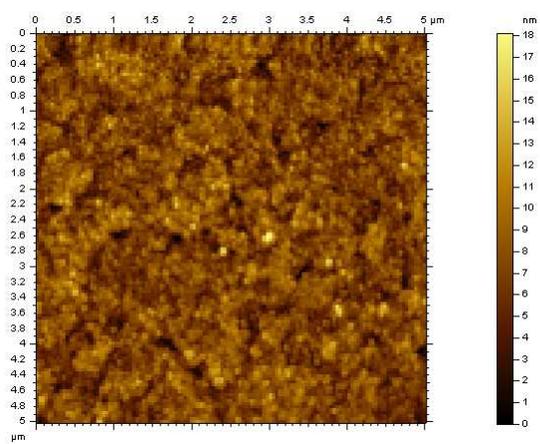
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(a)



(b)



(c)

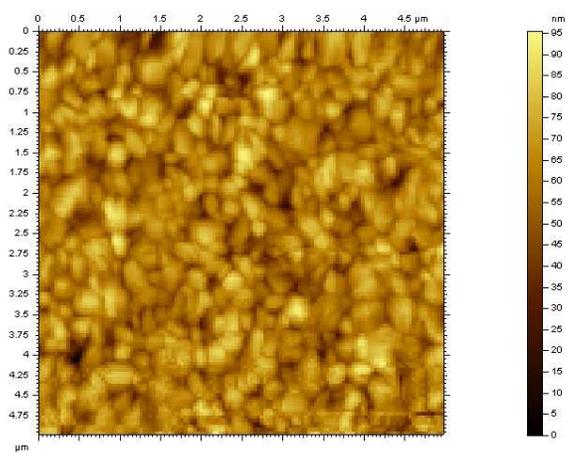


Figure S1. AFM topography images of (a) ITO/ SnO₂ film. (b) ITO/ZnO/ SnO₂ film. (c)

ITO/ZnO/ SnO₂/MAPbI₃ film.

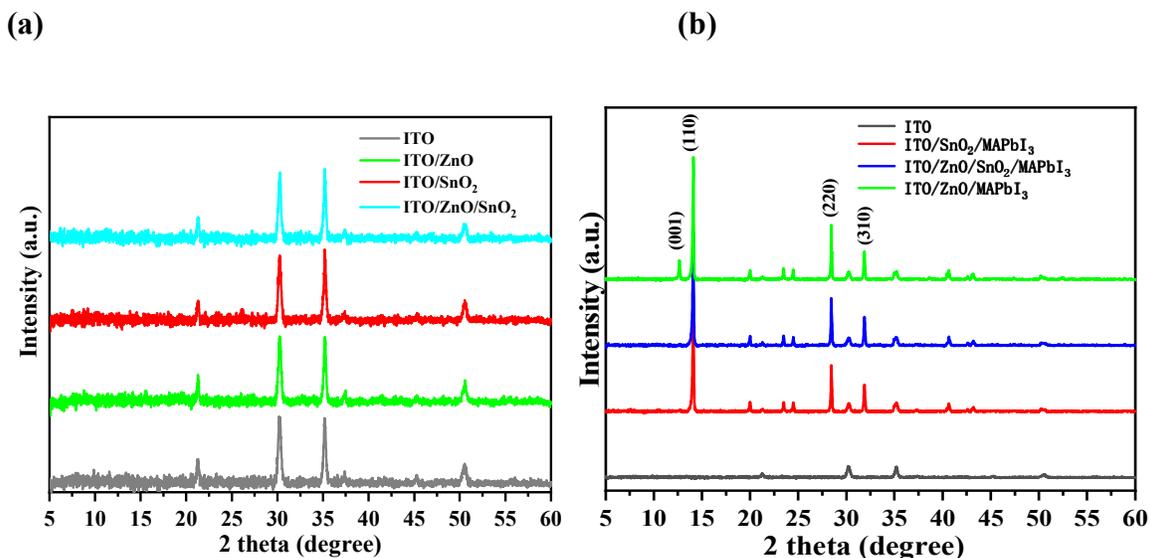


Figure S2. XRD patterns of different films on ITO/glass substrates. (a) ITO, ITO/ZnO, ITO/ SnO₂, and ITO/ZnO/ SnO₂ films. (b) ITO, ITO/ SnO₂/MAPbI₃, ITO/ZnO/ SnO₂/MAPbI₃, and ITO/ZnO/MAPbI₃ films.

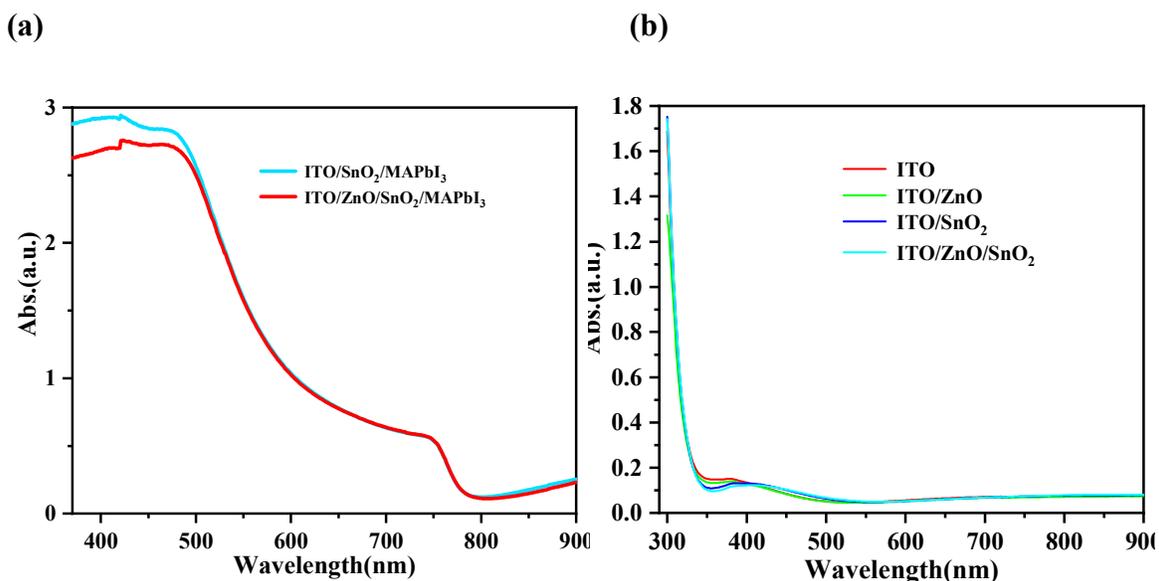


Figure S3. UV-Vis spectra of different films. (a) ITO, ITO/SnO₂/MAPbI₃, and ITO/ZnO/SnO₂/MAPbI₃ films. (b) ITO, ITO/ZnO, ITO/ SnO₂ and ITO/ZnO/ SnO₂ films.

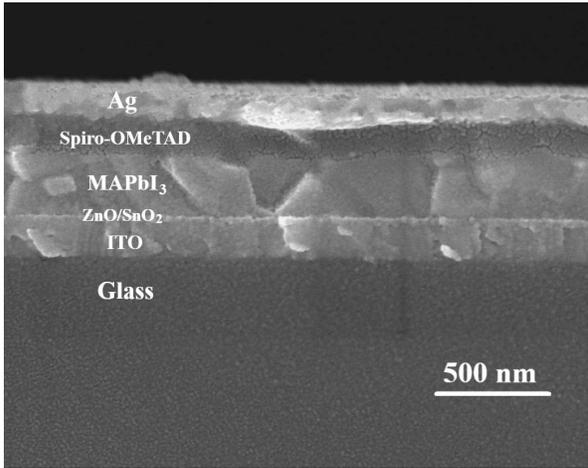


Figure S4. Cross-section SEM of the device with the structure of ITO/ZnO/SnO₂/MAPbI₃/Spiro-OMeTAD/Ag.

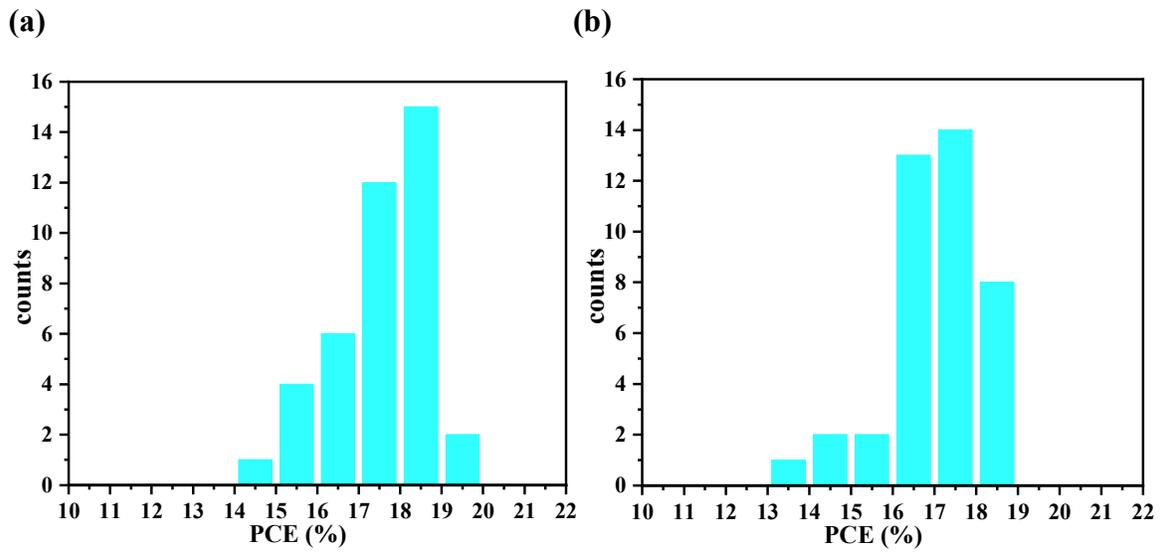


Figure S5. Histograms of PCEs measured for 40 cells. (a) Device S1. (b) Device S2.

Table S1. Comparison of the mean photovoltaic parameters of the perovskite solar cell based on ZnO/SnO₂ ETL with different thickness of ZnO.

Thickness of ZnO (nm)	Jsc (mA·cm ⁻²)	Voc (V)	FF	PCE (%)
0	22.77	1.05	0.736	17.6
45	21.86	1.10	0.707	17.0
65	21.48	1.13	0.758	18.4
80	20.85	1.11	0.713	16.5

Table S2. Comparison of photovoltaic parameters of the best perovskite solar cell. (1) ITO/ZnO/MAPbI₃/Spiro-OMeTAD/Ag. (2) ITO/ SnO₂/MAPbI₃/Spiro-OMeTAD/Ag (Device S2). (3) ITO/ZnO/SnO₂/MAPbI₃/Spiro-OMeTAD/Ag (Device S1).

Device	Jsc (mA·cm ⁻²)	Voc (V)	FF	PCE (%)
(1)	12.81	0.56	0.293	2.1
(2)	22.75	1.07	0.739	18.0
(3)	21.74	1.15	0.764	19.1

Table S3. Transient PL spectroscopy results of ZnO/ SnO₂/MAPbI₃ and

ZnO/SnO₂/MAPbI₃ on glass.

Sample	τ_1 (ns)	τ_1 ratio (%)	τ_2 (ns)	τ_2 ratio (%)	τ_3 (ns)	τ_3 ratio (%)	Average life time (ns)
SnO₂/MAPbI₃	3.84	56.0	24.07	39.0	132.56	5.0	17.70
ZnO/SnO₂/MAPbI₃	5.12	56.0	32.59	36.0	151.49	8.0	26.26