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Supporting Information

for *Adv. Sci.*, DOI: 10.1002/advs.202001466

Dual Passivation of Perovskite and SnO_2 for High-efficiency $MAPbI_3$ Perovskite Solar Cells

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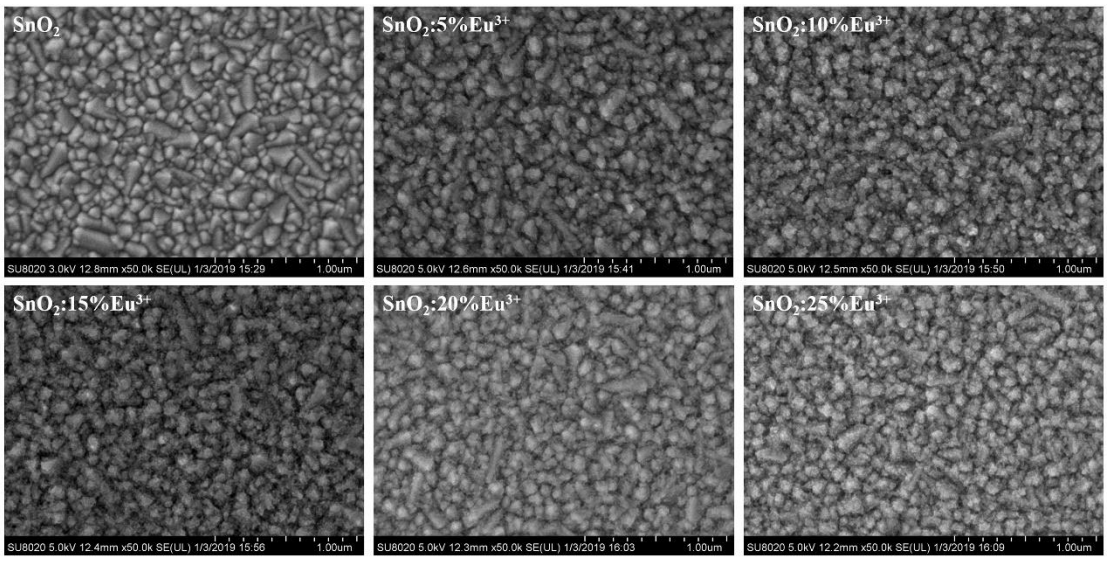

Fig. S1 The SEM images of SnO_2 and SnO_2:Eu^{3+} films.

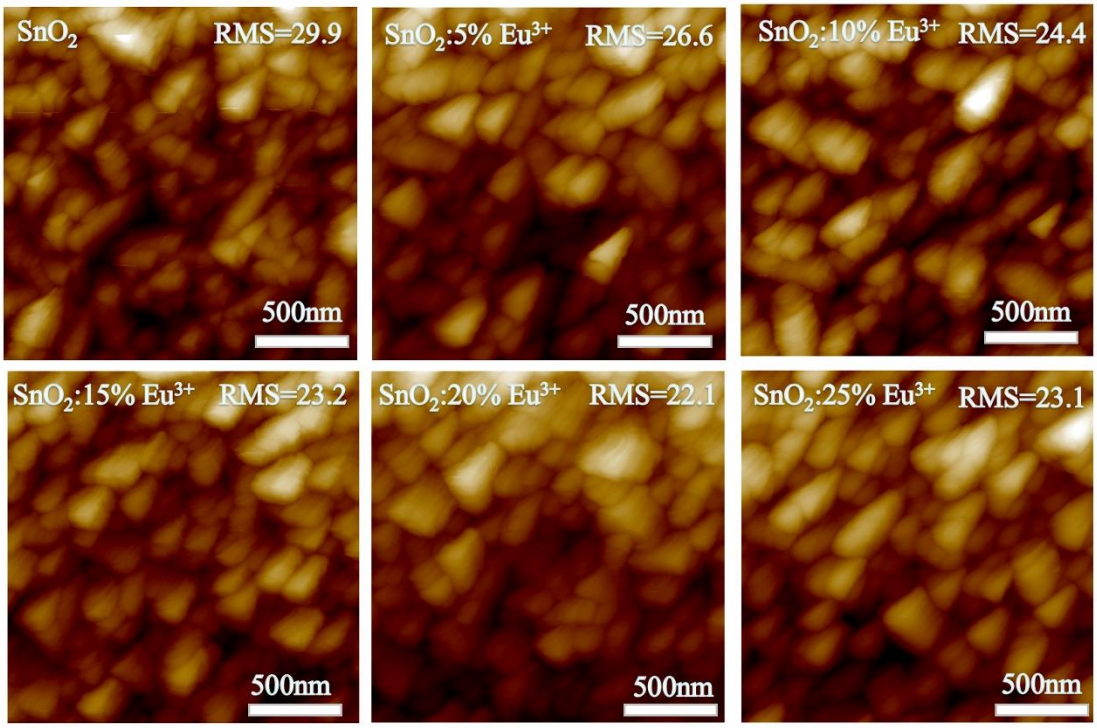

Fig. S2 Atomic force microscopy (AFM) images of SnO_2 and SnO_2:Eu^{3+} films deposited on FTO substrates

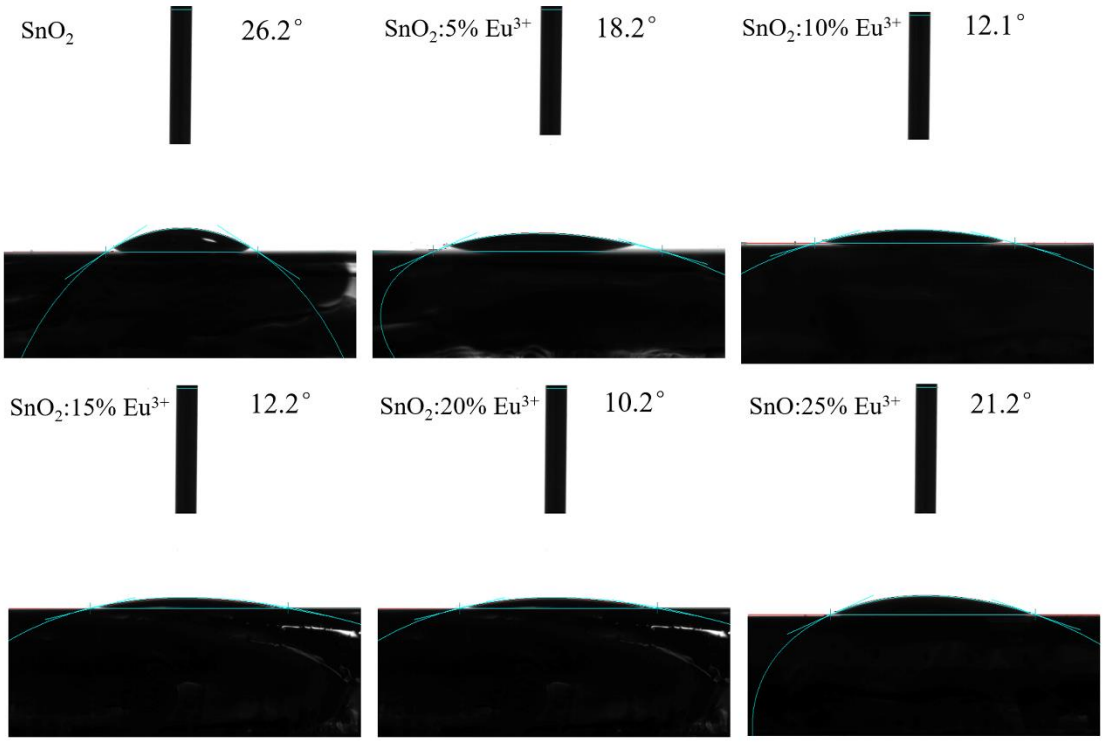

Fig. S3 The contact angles of SnO_2 and SnO_2:Eu^{3+} films.

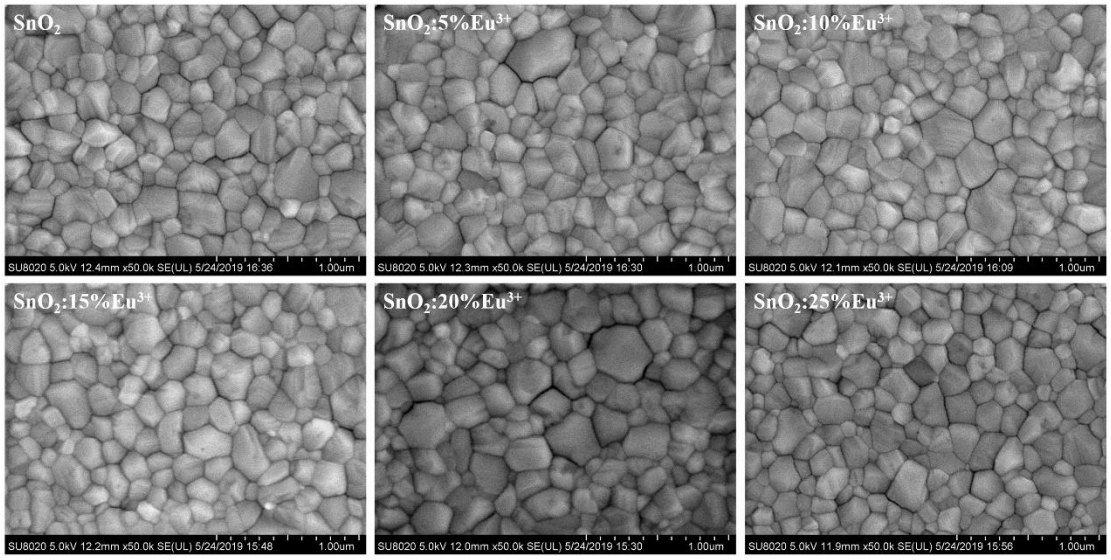

Fig. S4 The SEM images of perovskite films coated on SnO_2 and SnO_2:Eu^{3+} films.

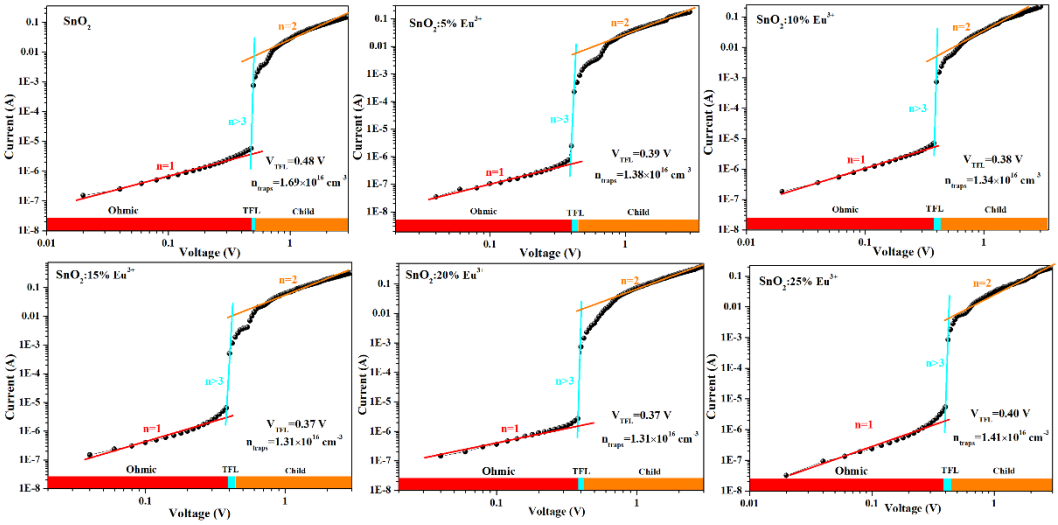

Fig. S5 Dark *I-V* curves of the electron-only devices with different ETL

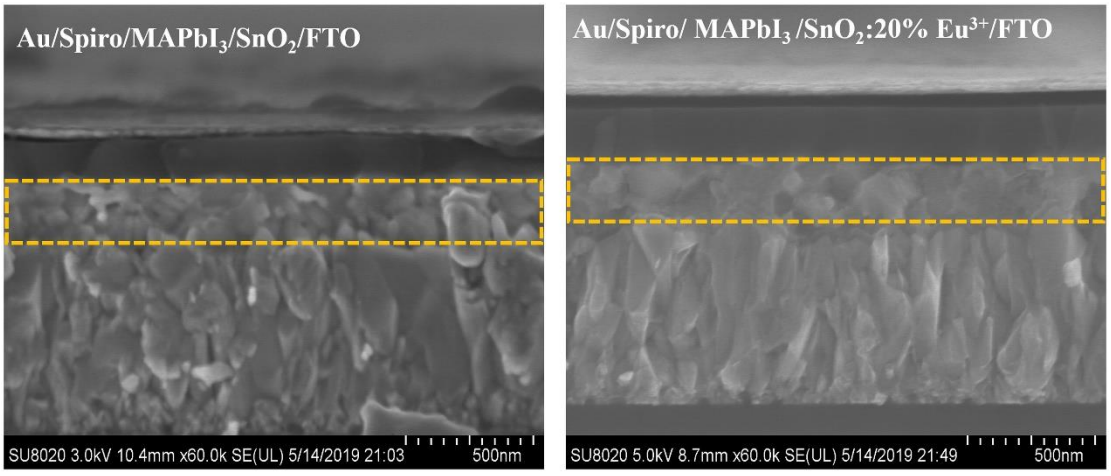

Fig. S6 The cross-sectional SEM images of PSCs with different ETL.

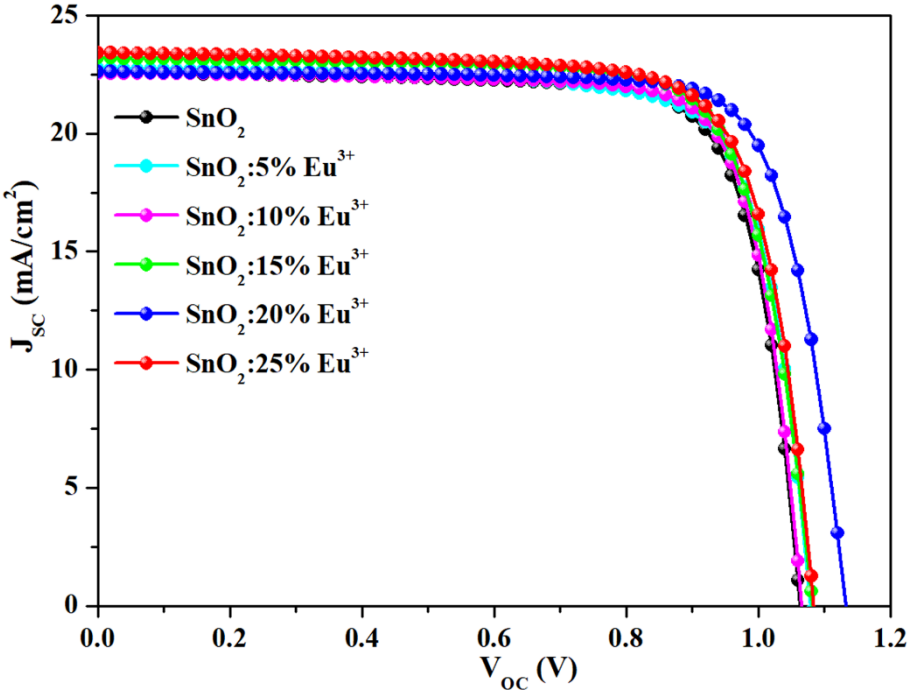

Fig.S7 *J-V* curves of the PSCs with different ETLs substrates.

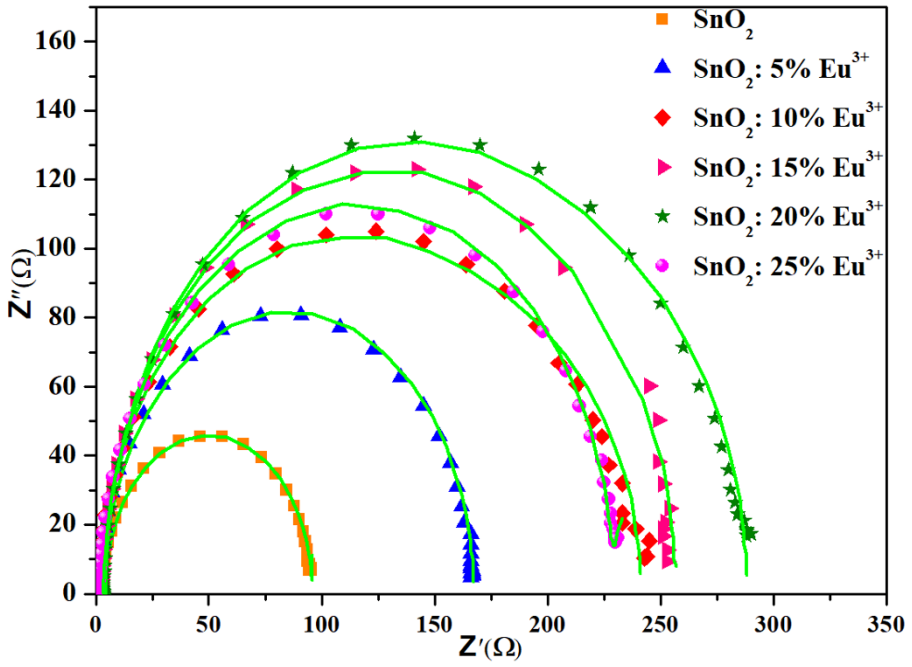

Fig.S8 EIS of planar-type PSCs with various ETLs.

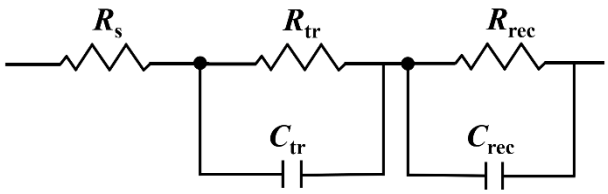

Fig.S9 Equivalent circuit in PSCs.

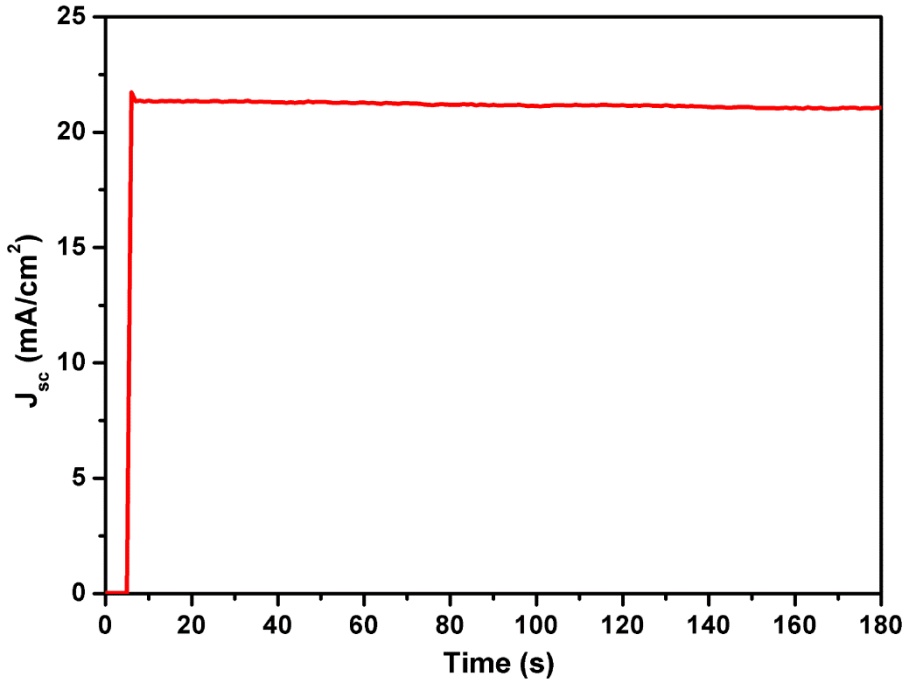

Fig.S10 Stable output curves of current densities of the device with SnO_2:Eu^{3+} at the maximum power point.

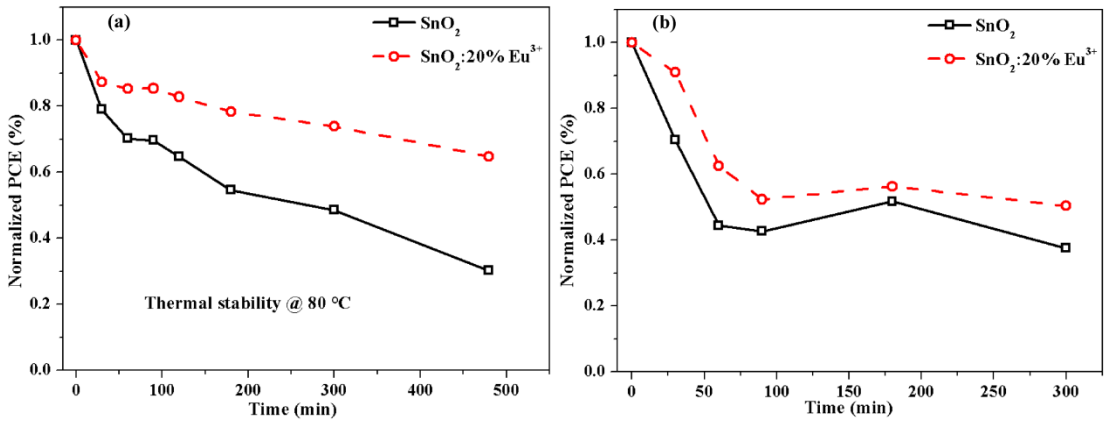

Fig.S11 Stability test for planar-type PSC devices with different ETLs without any encapsulation (a) at 80 °C in dry N_2 atmosphere; (b) under 100 mW cm^{-2} illumination and 40-50% humidity at 60 °C.

Supplementary Table 1 The average Hall coefficient, resistivity, mobility and carrier concentration of SnO_2 and SnO_2:20% Eu films.

Sample	Average Hall coefficient ($cm^3\ C^{-1}$)	Resistivity (Ω·cm)	Mobility ($cm^2\ V^{-1}\ s^{-1}$)	Carrier concentration (cm^{-3})
SnO_2	-2.59×10^5	6.24×10^2	4.14×10^2	-2.41×10^{13}
SnO_2:20% Eu	-3.18×10^5	3.36×10^2	9.44×10^2	-1.97×10^{13}

Supplementary Table 2 Parameters of the TRPL spectra of perovskite films deposited on different substrates.

Sample	τ_{ave} (ns)	τ_1 (ns)	% of τ_1	τ_2 (ns)	% of τ_2
FTO/SnO_2/Perovskite	35.20	4.38	39.5%	37.55	60.5%
FTO/SnO_2:5% Eu/Perovskite	17.45	3.94	33.08%	18.85	66.9%
FTO/SnO_2:10% Eu/Perovskite	6.07	2.93	43.59%	7.07	56.41%
FTO/SnO_2:15% Eu/Perovskite	6.16	2.76	38.71%	7.01	61.29%
FTO/SnO_2:20% Eu/Perovskite	4.54	7.65	13.05%	3.53	86.95%
FTO/SnO_2:25% Eu/Perovskite	9.85	3.04	36.32%	10.93	63.68%

Supplementary Table 3 Parameters of PSCs deposited on different substrates.

The amount of Eu^{3+} in SnO_2:Eu^{3+} (mol%)	V_{oc} **(V)**	J_{sc} **(mA cm^{-2})**	**FF**	**PCE (%)**
0	1.06	22.57	77.77	18.66
5	1.07	22.75	76.73	18.84
10	1.10	22.41	76.77	19.08
15	1.10	22.25	78.76	19.28
20	1.13	22.61	78.76	20.14
25	1.08	23.41	76.68	19.46