

Supporting Information

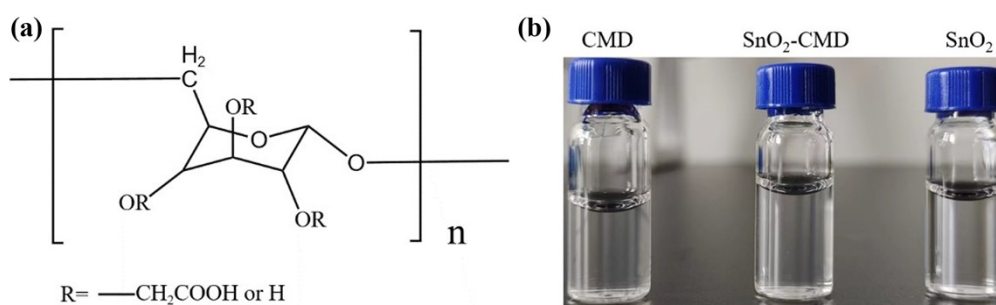


Figure S1. a) Molecular structure of CMD b) Photograph of the CMD, SnO₂, SnO₂+ CMD mixture in H₂O solution before and after oscillation.

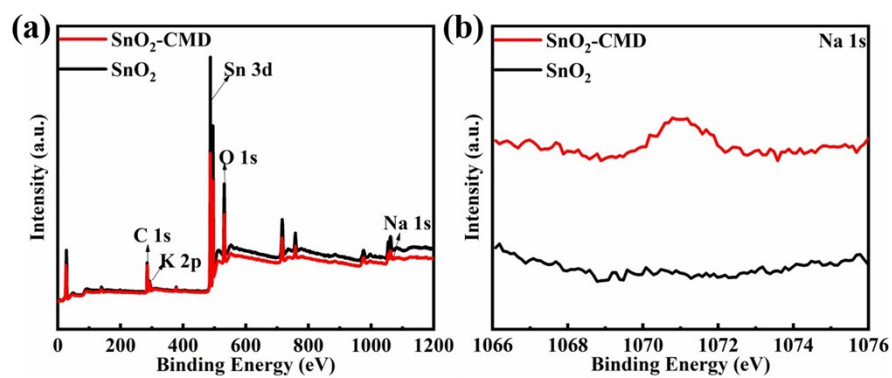


Figure S2 a) XPS spectra of SnO₂ and SnO₂-CMD survey b) Na 1s XPS spectra of SnO₂ and SnO₂-CMD films

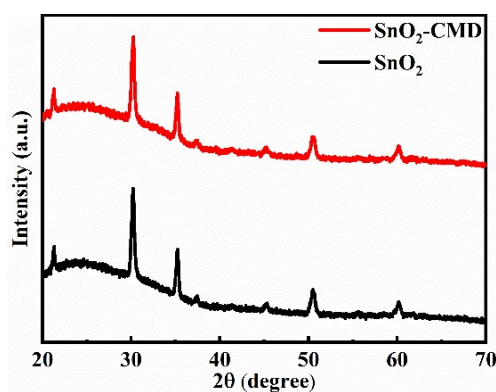


Figure S3 XRD patterns of ITO/SnO₂ and ITO/SnO₂-CMD films.

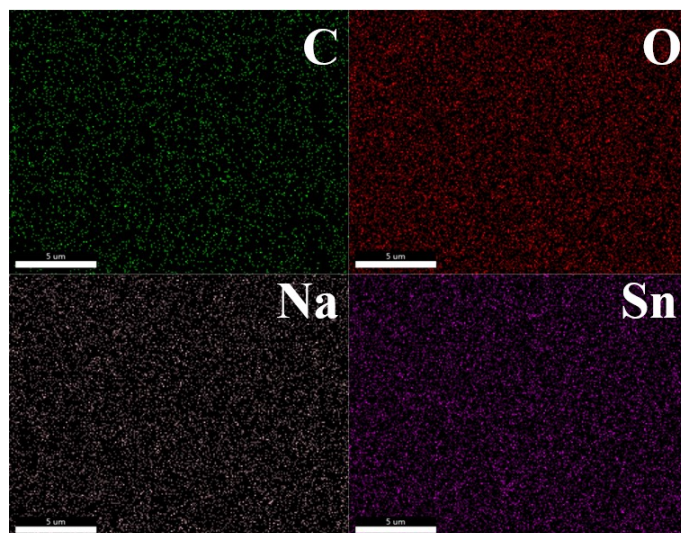


Figure S4 EDS element distribution mapping of SnO₂-CMD

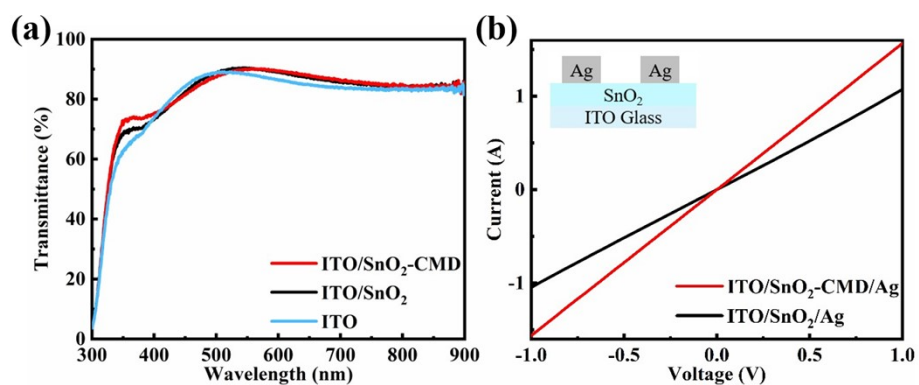


Figure S5 a) Optical transmittance spectra of ITO, SnO₂, and SnO₂-CMD films on ITO glass substrates. b) I–V curves of the devices of ITO/ETL/Ag with SnO₂ or SnO₂-CMD ETL. The inset shows the device structure for conductivity measurement.

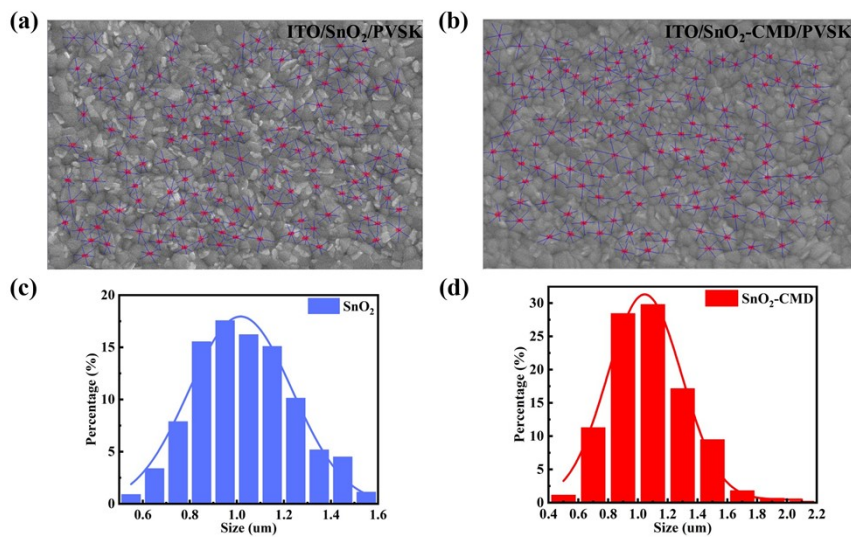


Figure S6. Screenshot of the calculation software for particulate size SnO₂ and SnO₂-CMD.

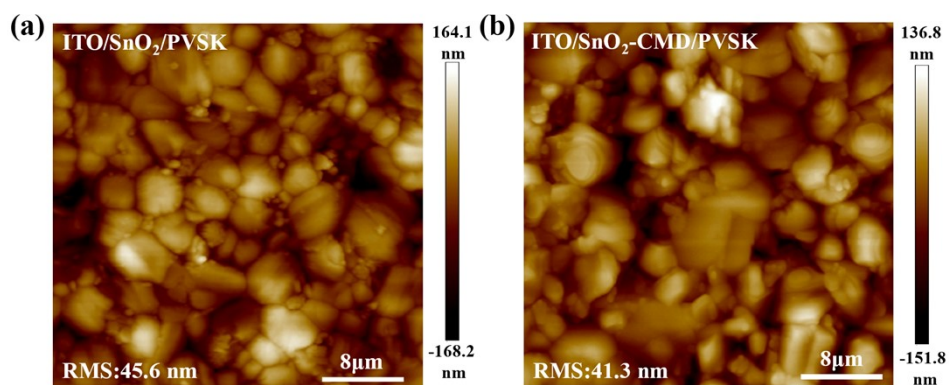


Figure S7. AFM images of (a) SnO₂/PVSK and (b) SnO₂-CMD/PVSK films.

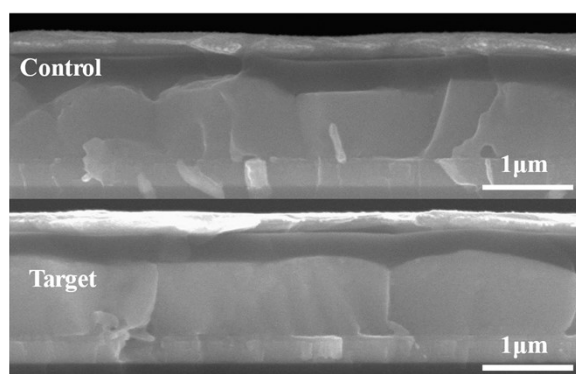


Figure S8 SEM cross-sectional view of the complete device based on the SnO₂(Control) and SnO₂-CMD (Target) perovskite solar cell.

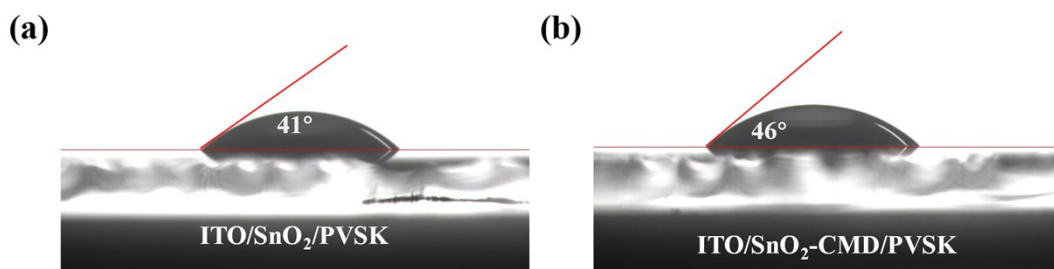


Figure S9 Contact angles for perovskite precursor on the SnO₂ and SnO₂-CMD films

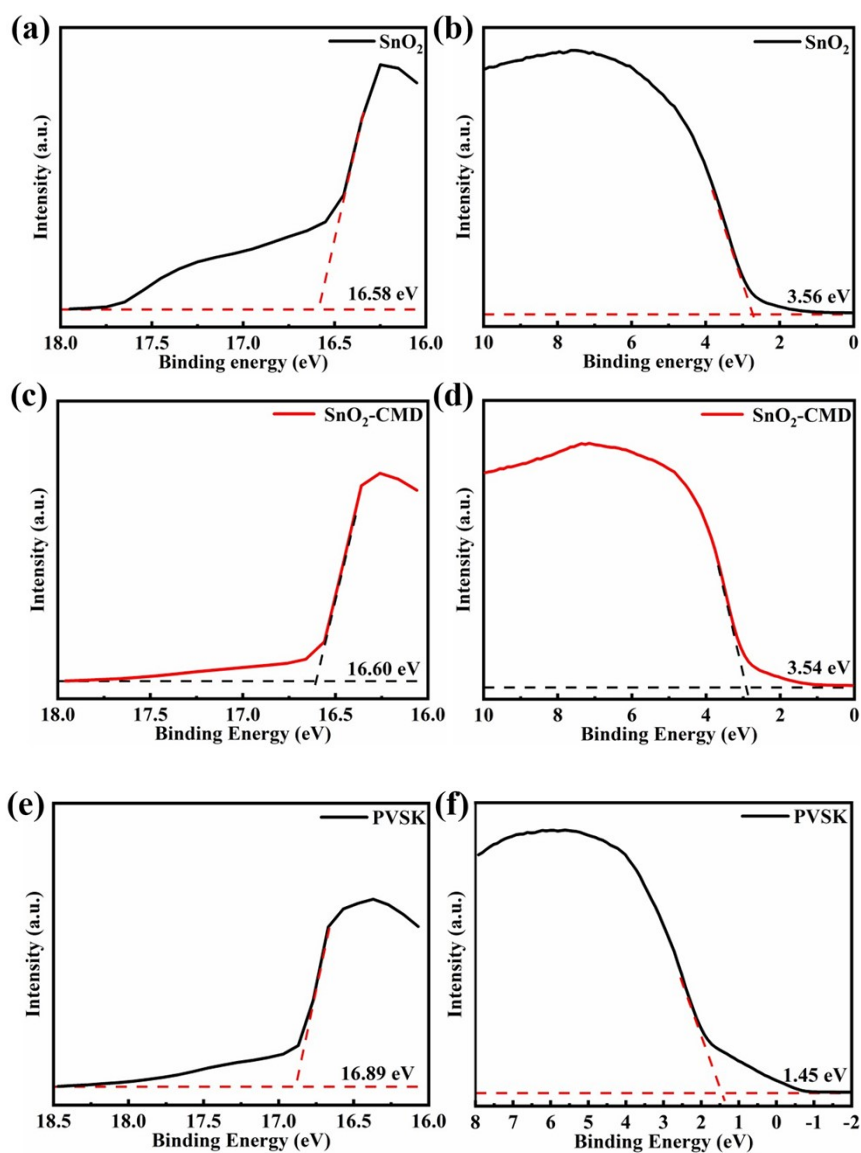


Figure S10 Ultraviolet photoelectron spectroscopy (UPS) of pristine SnO₂, SnO₂-CMD, and perovskite film.

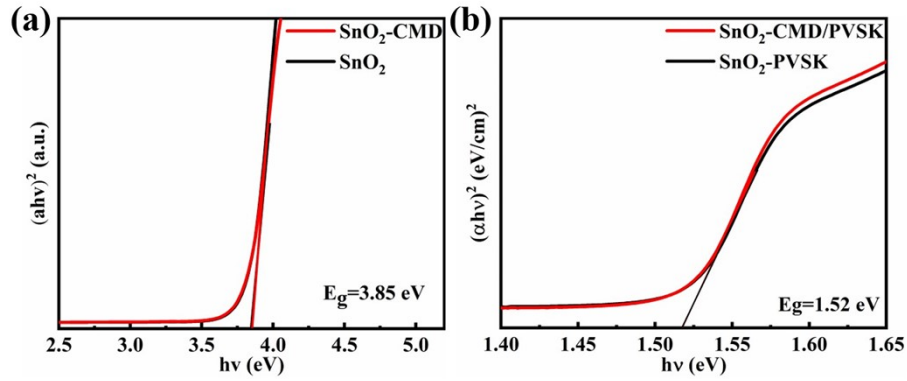


Figure S11 Tauc plots of the (a) SnO_2 and $\text{SnO}_2\text{-CMD}$ films. (b) Tauc plots of the perovskite films on SnO_2 and $\text{SnO}_2\text{-CMD}$

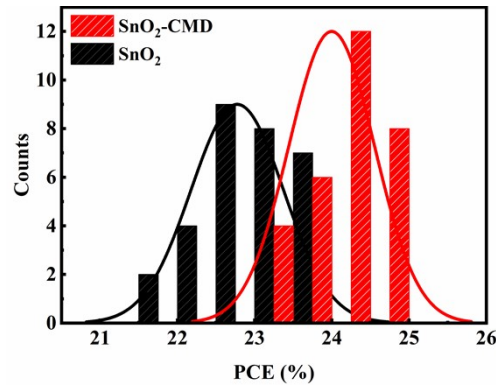


Figure S12 PCE distributions of PSCs with SnO_2 and $\text{SnO}_2\text{-CMD}$ ETL from 30 device statistics, respectively.

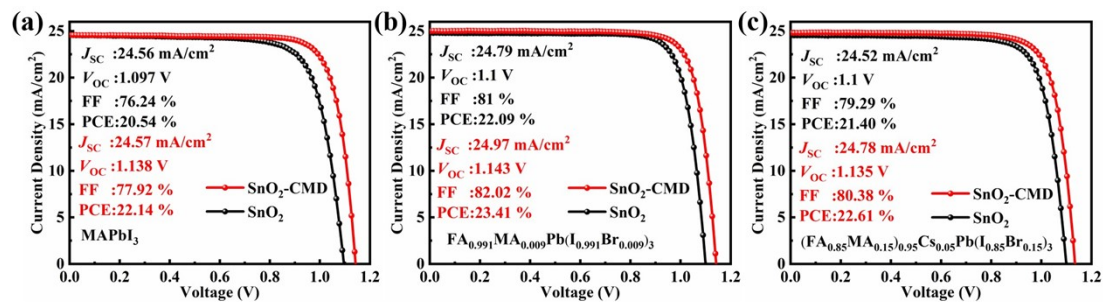


Figure S13. Based on SnO_2 and $\text{SnO}_2\text{-CMD}$ ETL, different perovskite compositions J-V curves of champion PSCs. (a) MAPbI_3 (b) $(\text{FA}_{0.85}\text{MA}_{0.15})_{0.95}\text{Cs}_{0.05}\text{Pb}(\text{I}_{0.85}\text{Br}_{0.15})_3$ (c) $\text{FA}_{0.991}\text{MA}_{0.009}\text{Pb}(\text{I}_{0.991}\text{Br}_{0.009})_3$

Table S1. Fitted results of TRPL spectra of the perovskite films deposited on pristine SnO₂ and SnO₂-CMD.

ETL	A ₁	τ_1 (ns)	A ₂	τ_2 (ns)	τ_{ave} (ns)
SnO ₂	0.15	90.30	0.85	180.70	173.37
SnO ₂ -CMD	0.12	45.47	0.88	140.30	136.29

Table S2. Photovoltaic performance parameters of PSCs made with different concentrations of CMD.

Concentration(mg/mL)	J_{sc} (mA/cm ²)	V_{oc} (V)	FF(%)	PCE(%)
0	24.64	1.140	82.19	23.09
0.5	25.07	1.158	83.36	24.20
1	25.16	1.158	84.89	24.73
1.5	25.12	1.157	83.96	24.40

Table S3. Photovoltaic data and hysteresis index of the pristine and CMD-modified PSCs.

ETL	Scan Direction	J_{sc} (mA/cm ²)	V_{oc} (V)	FF(%)	PCE(%)	HI
SnO ₂	Reverse	24.64	1.1402	82.19	23.09	0.0307
	Forward	24.65	1.1410	79.58	22.38	
SnO ₂ -CMD	Reverse	25.16	1.1582	84.89	24.74	0.0170
	Forward	25.08	1.1584	83.70	24.32	