

Supporting Information:

MDACl₂-modified SnO₂ film for efficient planar perovskite solar cells

Yaodong Xiao, Xiangqian Cui, Boyuan Xiang, Yanping Chen, Chaoyue Zhao, Lihong Wang, Chuqun Yang, Guangye Zhang, Chen Xie, Yulai Han, Mingxia Qiu *, Shunpu Li * and Peng You *

College of New Materials and New Energies, Shenzhen Technology University, Shenzhen, 518118, China.

* Correspondence: youpeng@sztu.edu.cn (P.Y.); lishunpu@sztu.edu.cn (S.L.); qiumingxia@sztu.edu.cn (M.Q.)

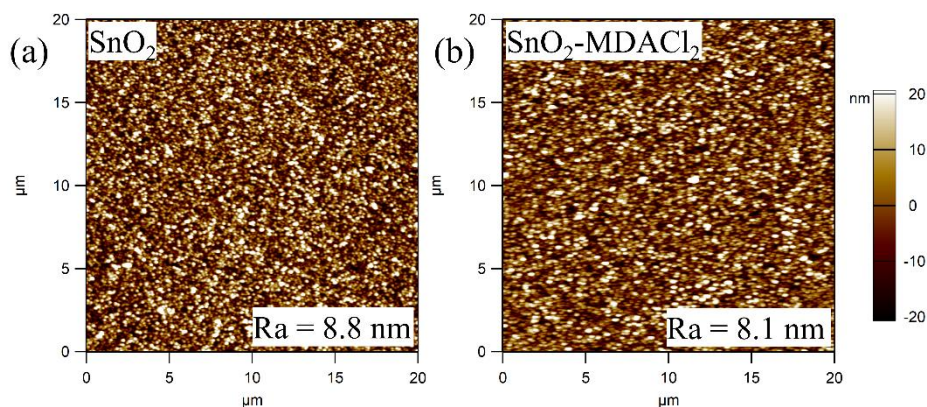


Figure S1. (a,b) AFM images of SnO_2 and $\text{SnO}_2\text{-MDACl}_2$ films grown on glass substrates.

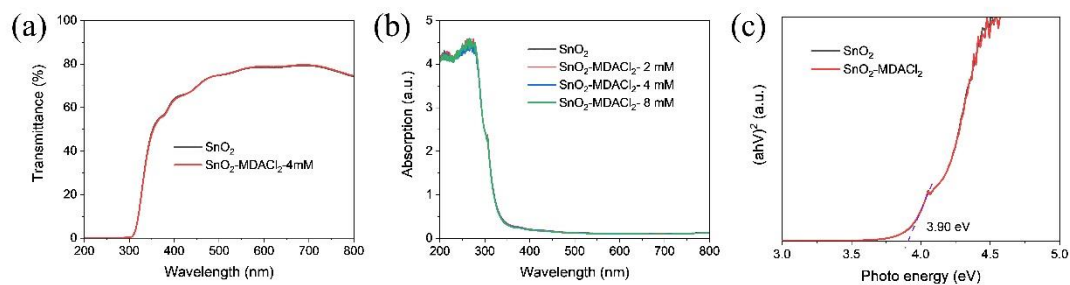


Figure S2. (a) Transmission spectra, (b) absorption spectra and (c) Tauc plots for the SnO_2 and $\text{SnO}_2\text{-MDACl}_2$ films.

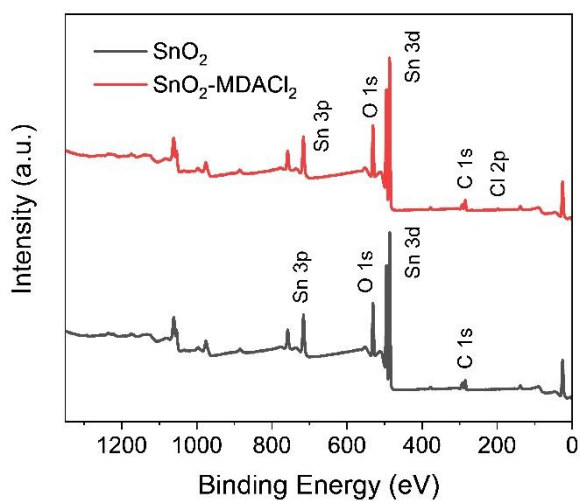


Figure S3. Full XPS spectra of the SnO_2 , $\text{SnO}_2\text{-MDACl}_2$ films.

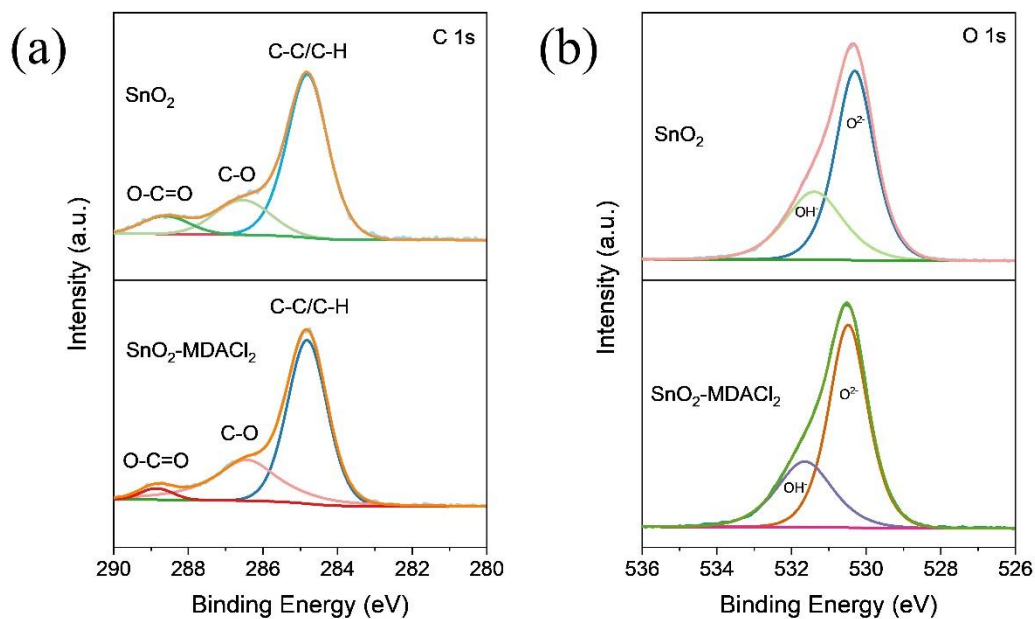


Figure S4. High-resolution (a) $\text{C } 1s$ and (b) $\text{O } 1s$ XPS spectra of the SnO_2 and $\text{SnO}_2\text{-MDACL}_2$ films.

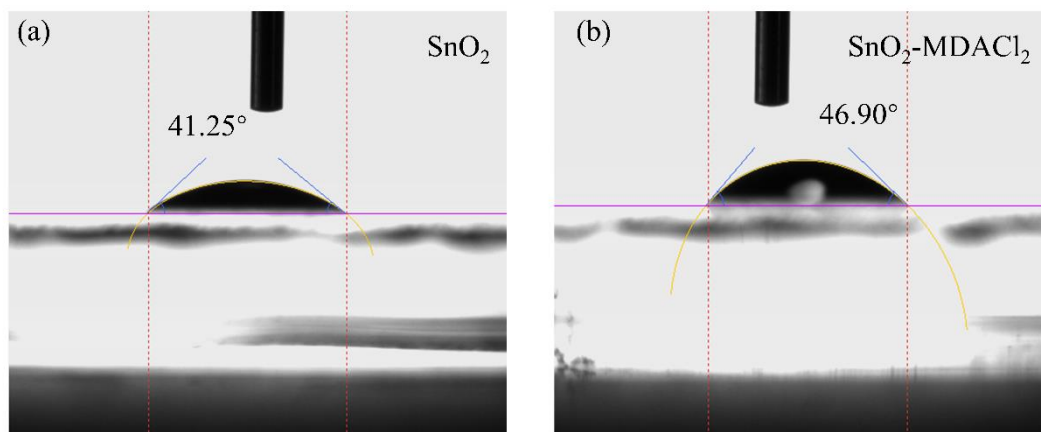


Figure S5. Contact angles of water droplets on the (a) SnO_2 and (b) $\text{SnO}_2\text{-MDACL}_2$ films.

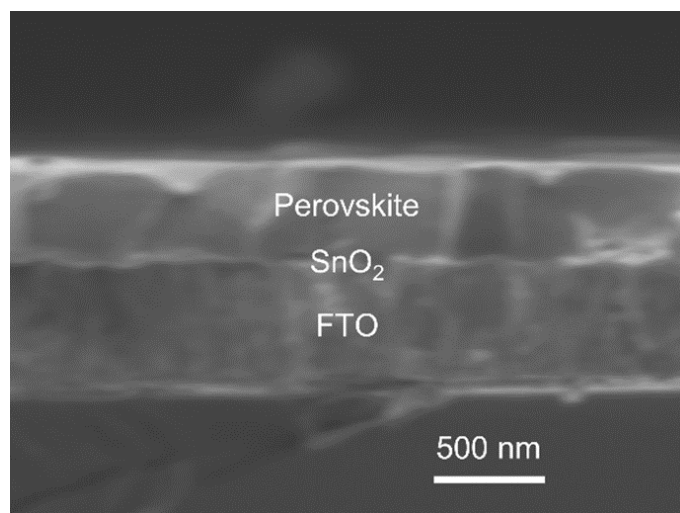


Figure S6. Cross-sectional SEM image of FTO/ SnO₂-MDACL₂/perovskite sample.

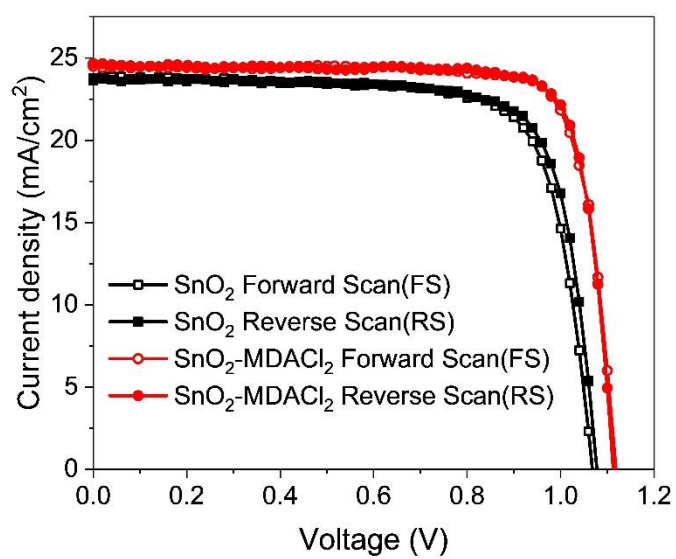


Figure S7. J-V curves of the PSCs based on SnO₂ and SnO₂-MDACL₂ ETLs under reverse scan and forward scans.

Table S1. Photovoltaic parameters of PSCs prepared by using MDACl₂-incorporated SnO₂ precursor solution and direct spin-coating MDACl₂ solution (4mM) on top of the SnO₂ film (statistical data of 20 devices for each conditions).

ETL	Voc (V)	Jsc (mA/cm ²)	FF (%)	PCE (%)
SnO ₂	1.075±0.010	23.35±0.39	75.39±1.42	18.92±0.47
SnO ₂ +MDACl ₂ (mixed precursor solution)	1.105±0.007	24.45±0.22	79.65±1.24	21.53±0.38
SnO ₂ /MDACl ₂ (direct spin-coating)	1.098±0.009	24.09±0.14	77.10±1.23	20.41±0.44

Table S2. Band gaps (E_g), secondary-electron cutoff (E_{cutoff}), fermi level (E_F), valence band (E_{VB}) and conduction band (E_{CB}) for SnO₂ film and SnO₂-MDACl₂ films.

ETL	E _g (eV)	E _{cutoff} (eV)	E _F (eV)	E _{VB} (eV)	E _{CB} (eV)
SnO ₂	3.90	15.72	5.50	8.29	4.39
SnO ₂ -MDACl ₂	3.90	15.56	5.66	8.13	4.23

Table S3. Conductivities of FTO/SnO₂-MDACl₂/Ag with different doping concentrations.

ETL	SnO ₂	SnO ₂ -MDACl ₂ 2mM	SnO ₂ -MDACl ₂ 4mM	SnO ₂ -MDACl ₂ 8mM
Conductivity (mS/cm)	2.73×10 ⁻³	4.26×10 ⁻³	5.27×10 ⁻³	4.13×10 ⁻³

Table S4. Fitting parameters of the TRPL spectra for Glass/FTO/SnO₂/perovskite films. The average time constant τ_{ave} was calculated according to the equation: $\tau_{ave} = (A_1\tau_1^2 + A_2\tau_2^2) / (A_1\tau_1 + A_2\tau_2)$.

ETL	A ₁	τ_1 (ns)	A ₂	τ_2 (ns)	τ_{ave} (ns)
SnO ₂	0.625	21.84	0.457	110.10	91.27
SnO ₂ -MDACl ₂	0.886	11.67	0.140	91.23	55.64

Table S5. Fitting values of R_s and R_{rec} of the corresponding devices in dark state

ETL	R_s (Ω)	R_{rec} (Ω)
SnO ₂	37.16	217.3
SnO ₂ -MDACl ₂	30.78	337.3