Supporting Information

Choline Chloride-Modified SnO_2 Achieving High Output Voltage in $MAPbI_3$ Perovskite Solar Cells

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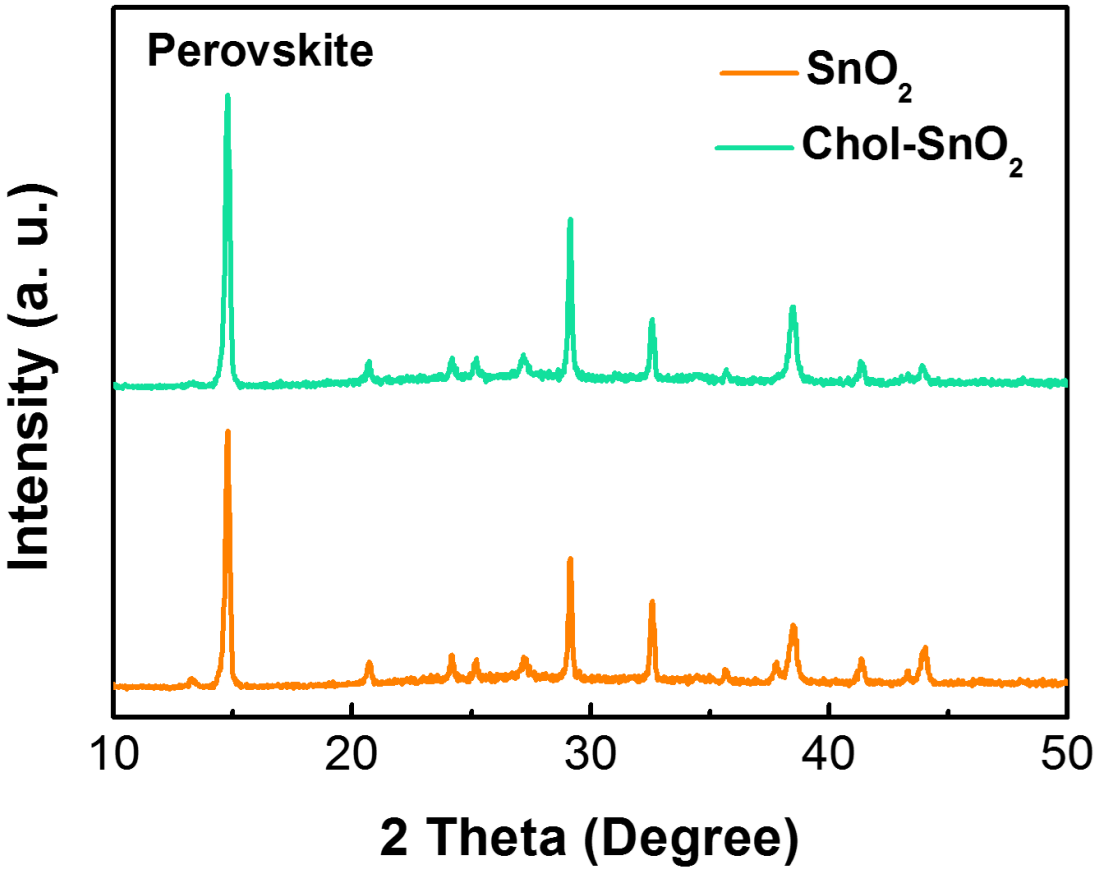

Figure S1. XRD patterns of perovskites were deposited on SnO_2 and Chol-SnO_2.

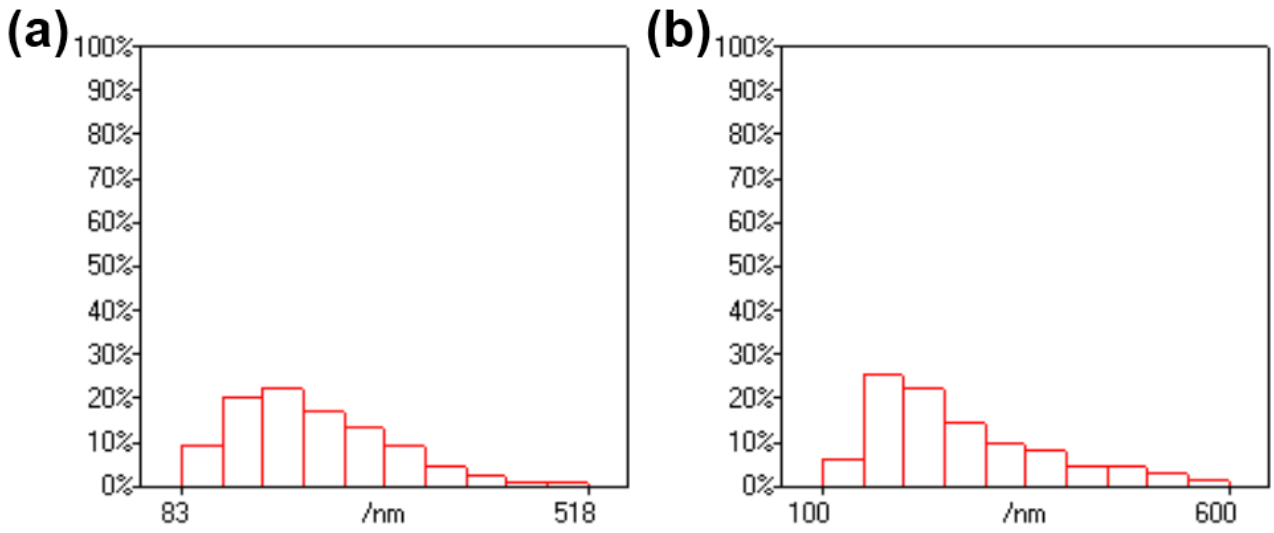

Figure S2. Grain size distribution of perovskite films deposited on a) SnO_2, b) Chol-SnO_2.

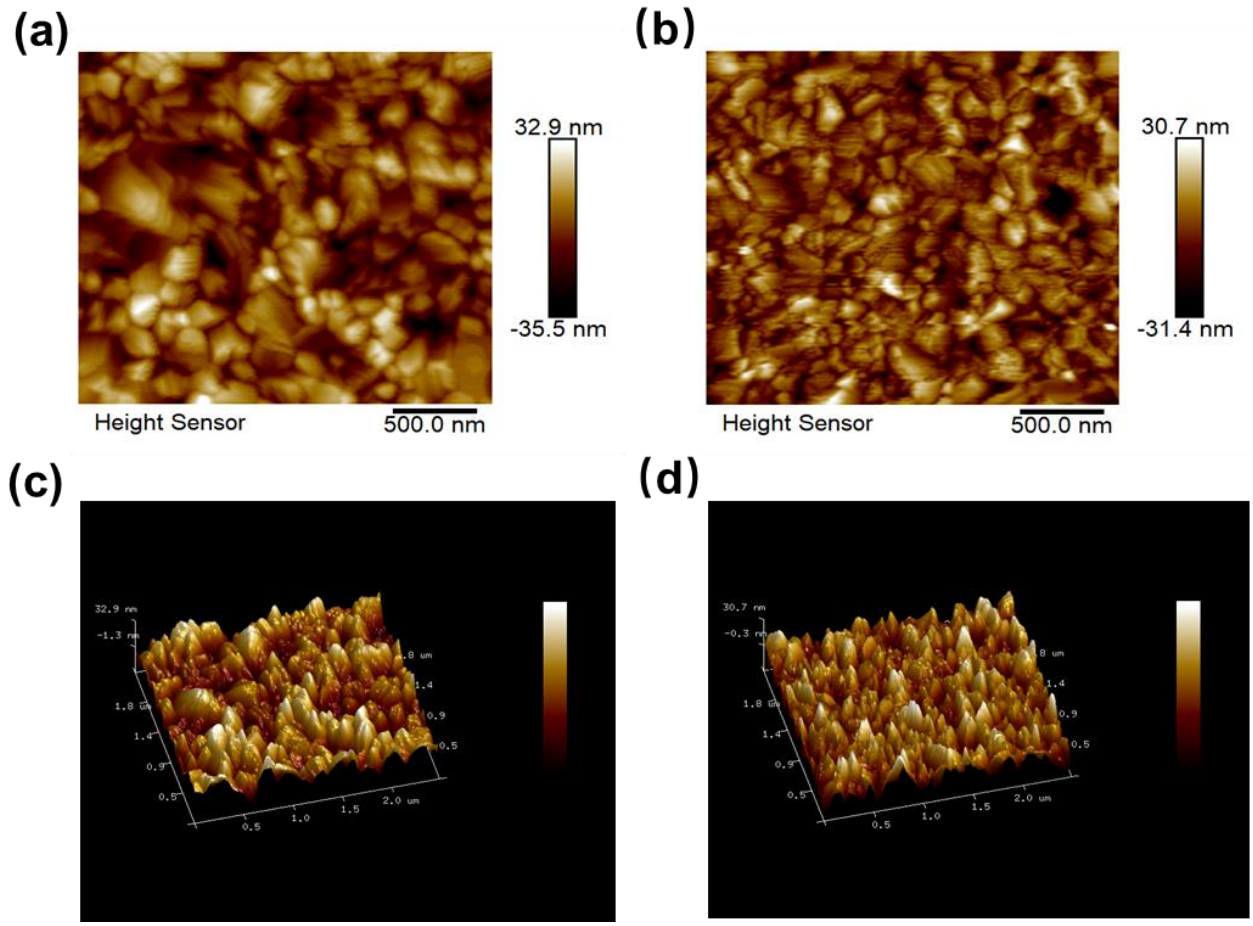

Figure S3. AFM images: Surface morphology of perovskite film deposited on a, c) SnO_2 and b, d) Chol-SnO_2.

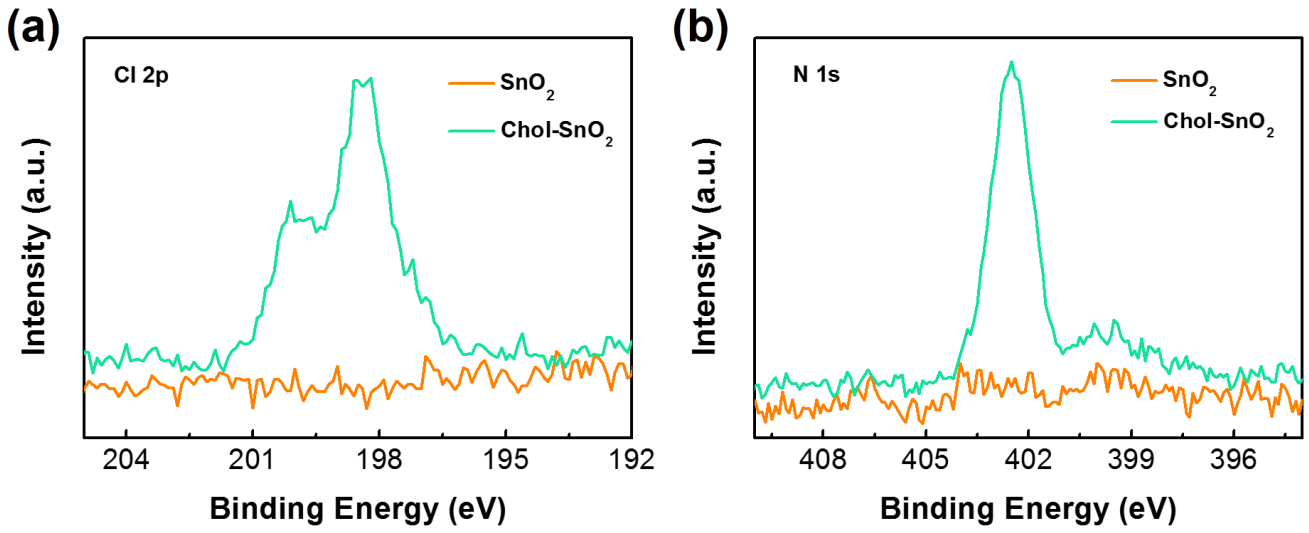

Figure S4. XPS fine spectrum of a) N 1s and b) Cl 2p on the SnO_2 and Chol-SnO_2.

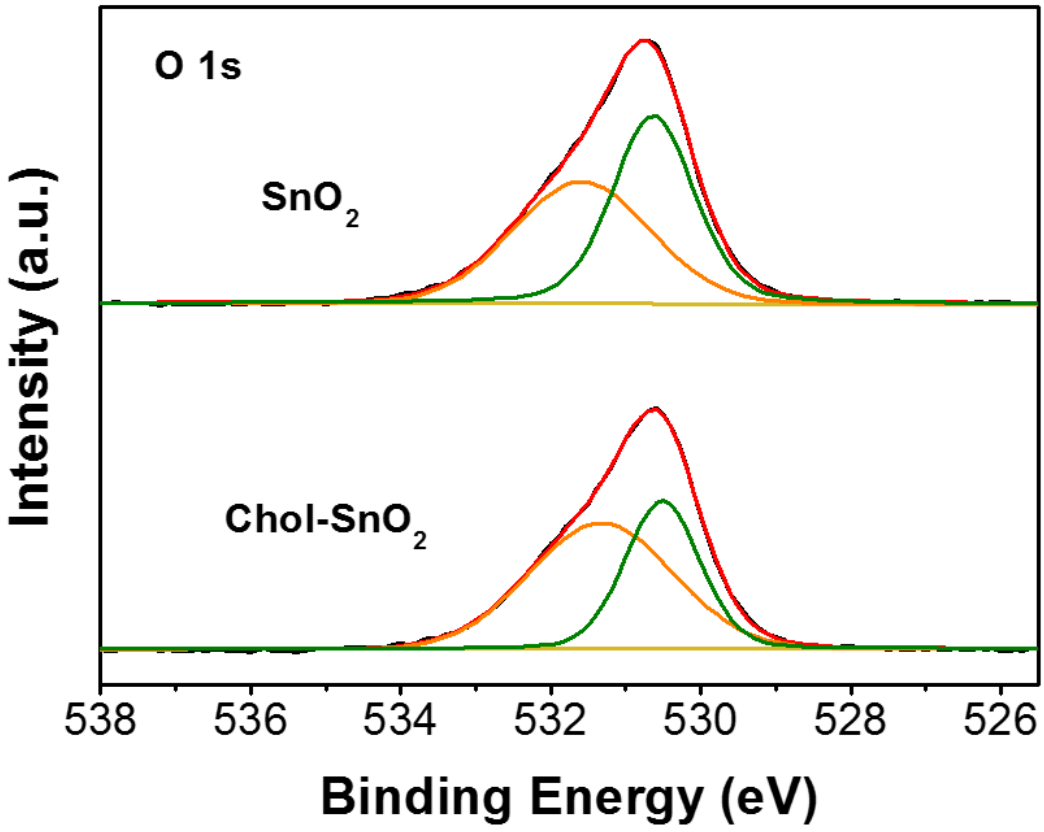

Figure S5. XPS curve of SnO_2 and Chol-SnO_2 at O 1s level.

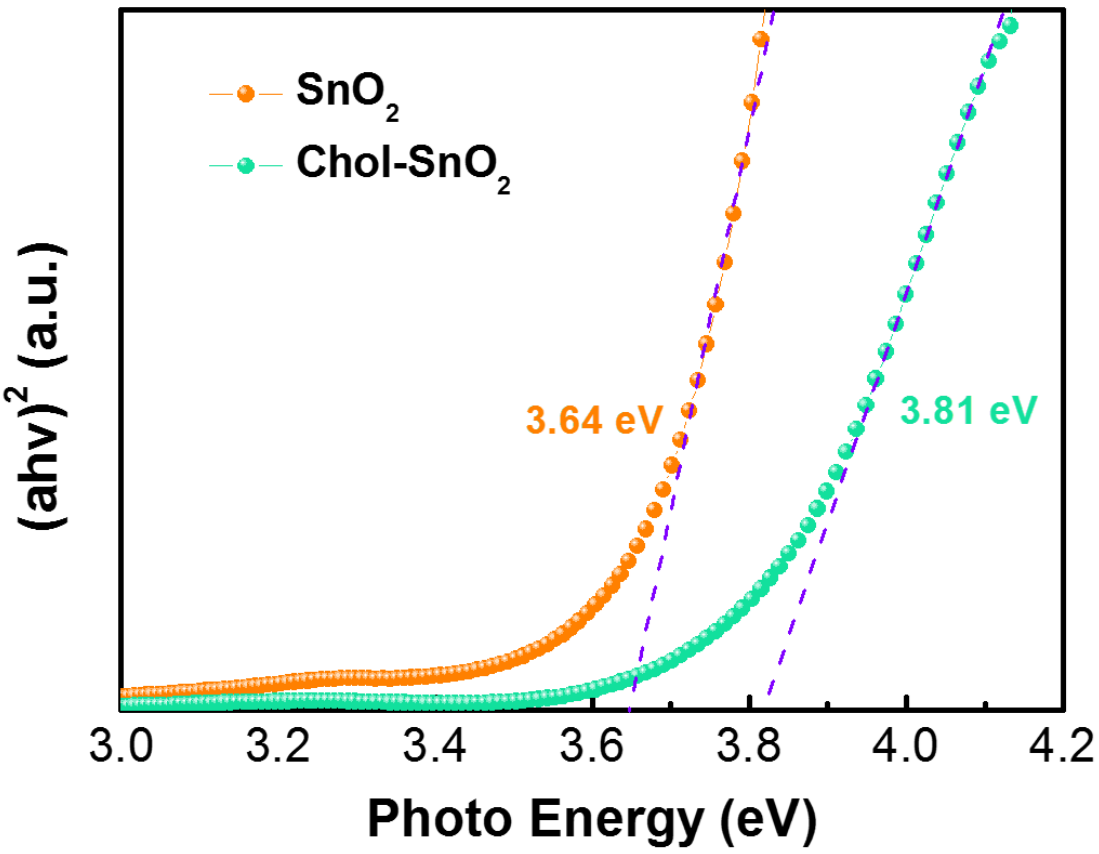

Figure S6. UV−vis spectra of SnO_2 and Chol-SnO_2.

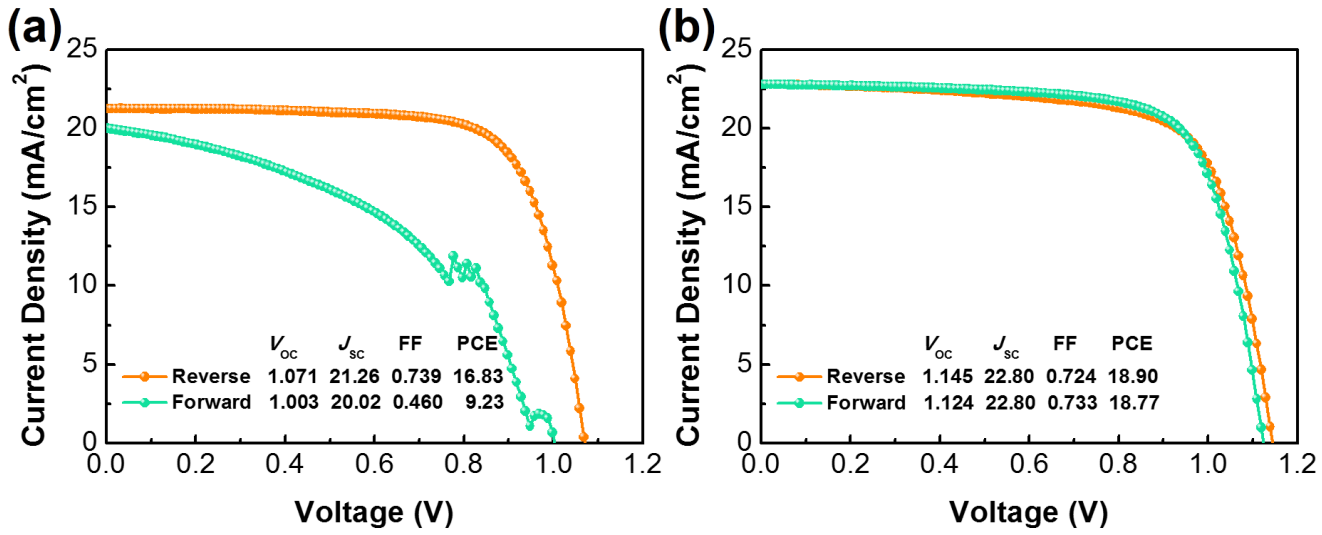

Figure S7. *J*–*V* curves of the devices having a) SnO_2 and b) Chol-SnO_2 for forward and reverse scanning.

Table S1. Band gaps (E_g), secondary−electron cutoff (E_{cutoff}), fermi level (E_F), valence band (E_{VB}) and conduction band (E_{CB}) for bare SnO_2 film and Chol-SnO_2 film.

Samples	E_g (eV)	E_{cutoff} (eV)	E_F (eV)	E_{VB} (eV)	E_{CB} (eV)
SnO_2	3.64	16.34	4.88	7.90	4.26
Chol-SnO_2	3.81	16.59	4.63	7.80	3.99

In order to get the Fermi level (E_F), we use E_F=E_{cutoff} − 21.22 eV, where E_{cutoff} is cutoff binding energy, and 21.22 eV is emission energy from He irradiation. The E_{cutoff} of SnO_2 and Chol-SnO_2 film are 16.34 and 16.59 eV, respectively. The E_F of SnO_2 and Chol-SnO_2 film are calculated as −4.88 and −4.63 eV, respectively. The E_{VB} of SnO_2 and Chol-SnO_2 film are −7.90 and −7.80 eV, calculating as E_{VB}= E_F − $E_{F,\ edge}$ (Fermi edge). According to the absorption spectrum and Tauc plot, we get the band gap (E_g) of SnO_2 (3.64 eV) and the Chol-SnO_2 (3.81 eV). Their E_{CB} obtained from E_g and E_{VB} is −4.26 and −3.99 eV, respectively.

Table S2. Fitting parameters of bi−exponential decay function in TRPL spectra.

Samples	A_1	τ_1	A_2	τ_2	Average decay time τ (ns)[a]
SnO_2	0.464	28.07	0.609	366.3	219.9
Chol-SnO_2	0.208	16.27	0.810	122.1	100.5

[a] Average decay time is calculated according to the equation: $\tau = (A_1\tau_1 + A_2\tau_2)/(A_1 + A_2)$.

Table S3. The fitted parameters for EIS measurements acquired under dark based on different samples.

Samples	R_s (Ω cm^2)	R_{rec} (Ω cm^2)
SnO_2	0.73	7.94×10^3
Chol-SnO_2	1.19	1.85×10^4