Supporting Information

A Facile Solution-Based Aluminum Oxide Interface layer for Enhancing the Efficiency and Stability of Perovskite Solar Cells

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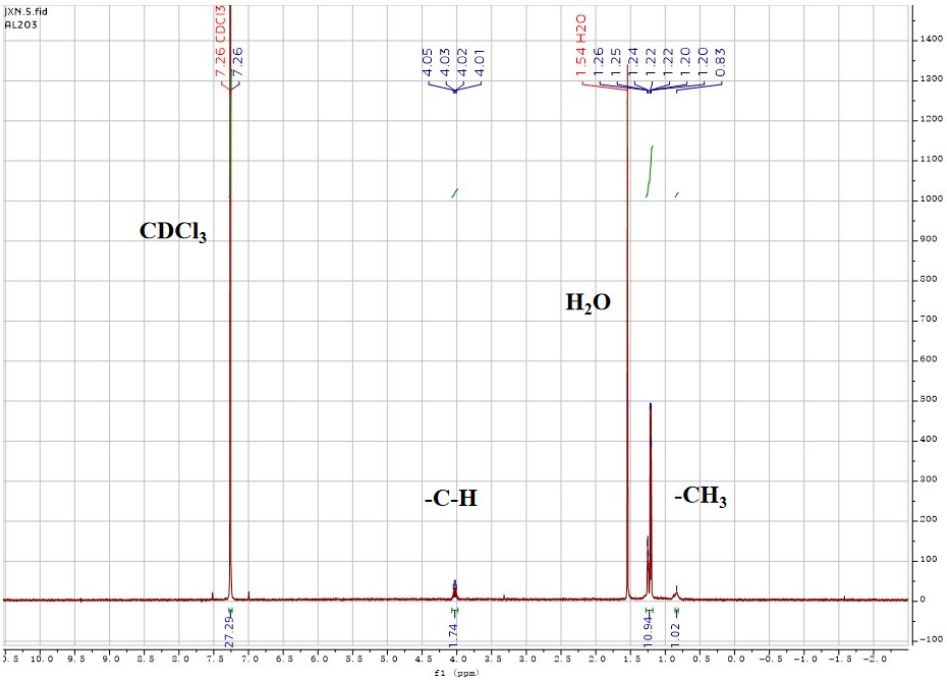

Figure S1. ^{1}H NMR spectra of the Al_2O_3 sample derived from ATIP. ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.52 (h, 1H, -CH), 1.25 (d, 6H, $-CH_3$). The result suggests that a certain amount of aluminum isopropoxide remains in the Al_2O_3 film.

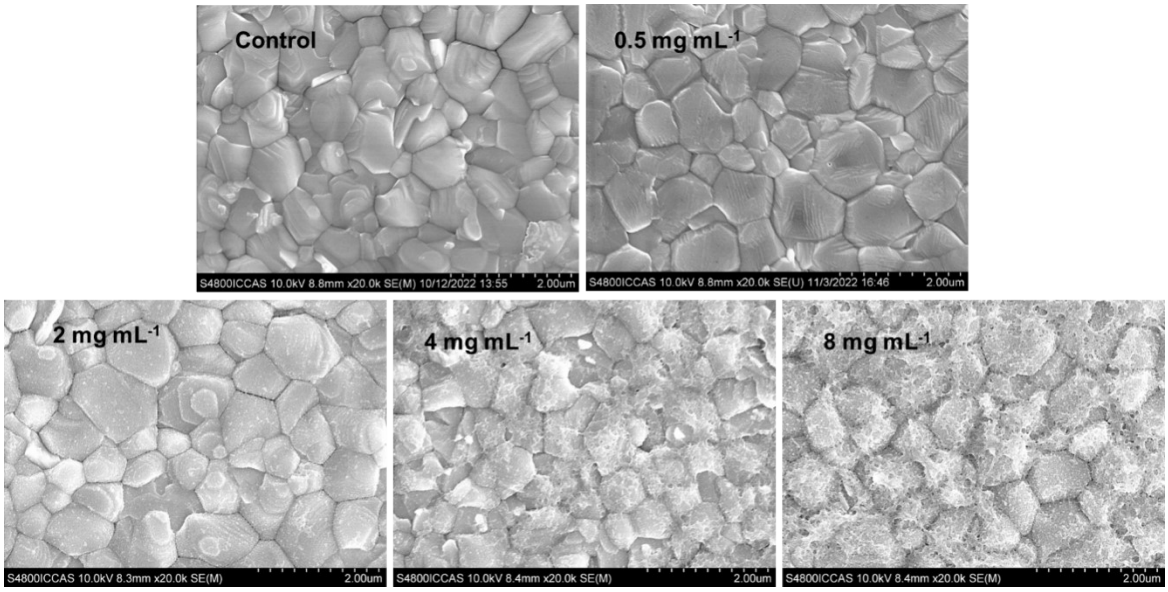

Figure S2. Top-view SEM images of the Al_2O_3-modified perovskite films from ATIP solution with various concentrations (0-8 mg mL^{-1}).

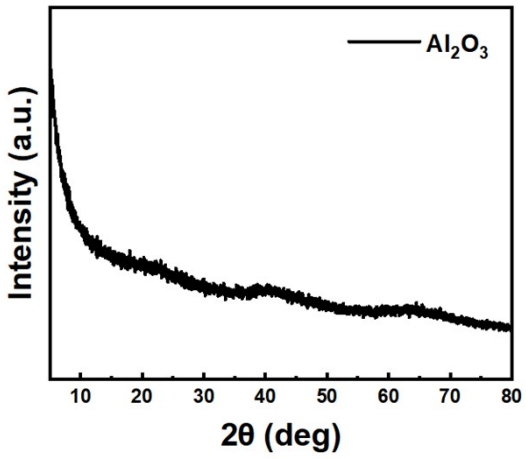

Figure S3. XRD patterns of the Al_2O_3 film deposited on a glass substrate using ATIP as precursor with thermal annealing at 150 °C in air (RH~40%).

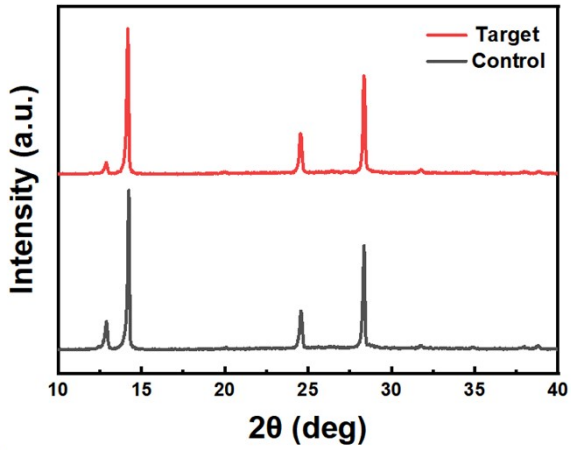

Figure S4. XRD patterns of the control (without Al_2O_3) and target (with Al_2O_3) perovskite films.

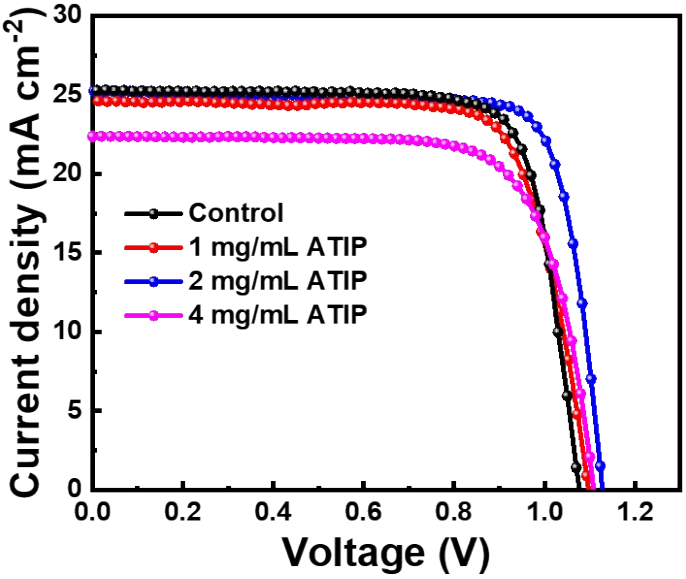

Figure S5. *J-V* curves of the PSCs modified by Al_2O_3 with various concentrations of ATIP.

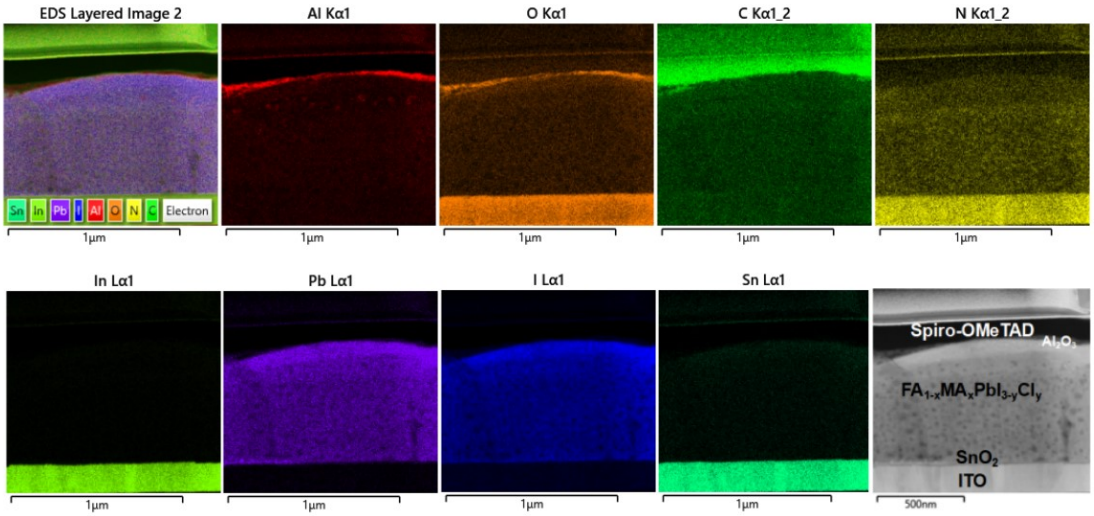

Figure S6. High angle annular dark field scanning TEM images of the device with individual and overlapped elemental maps of Al, O, Pb, I, C, N, Sn and In.

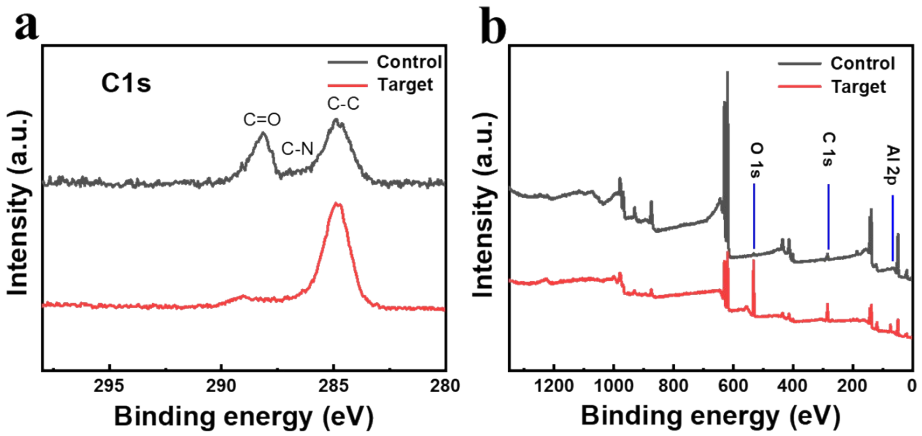

Figure S7. X-ray photoelectron spectroscopy (XPS) spectra of C 1s (a), and full XPS spectra (b) of the perovskite films with and without the Al_2O_3 modification.

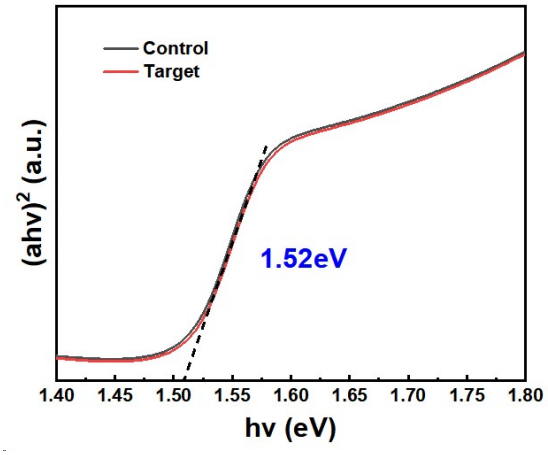

Figure S8. Tauc plots of the control and target perovskite films.

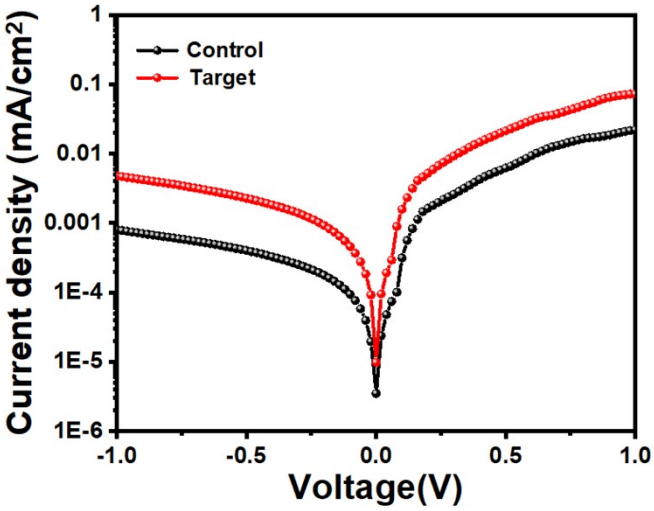

Figure S9. Dark *J-V* measurements of the control and target PSCs with a configuration of FTO/SnO_2/perovskite/(Al_2O_3)/Spiro-OMeTAD/Ag.

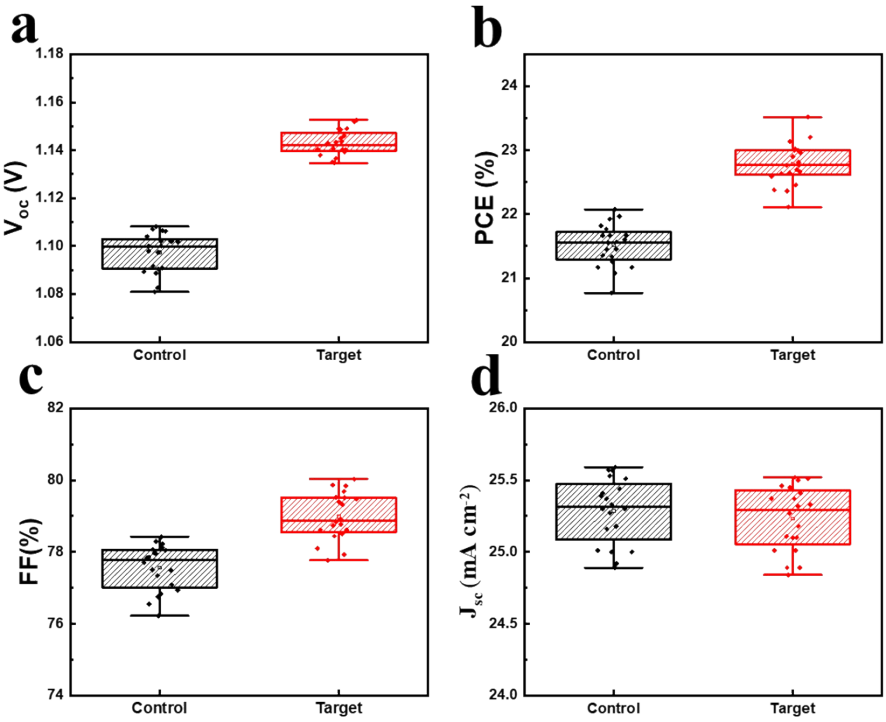

Figure S10. Statistic diagrams of *Voc* (a), PCE (b), *FF* (c), and *Jsc* (d) from 20 individual devices for each sample.

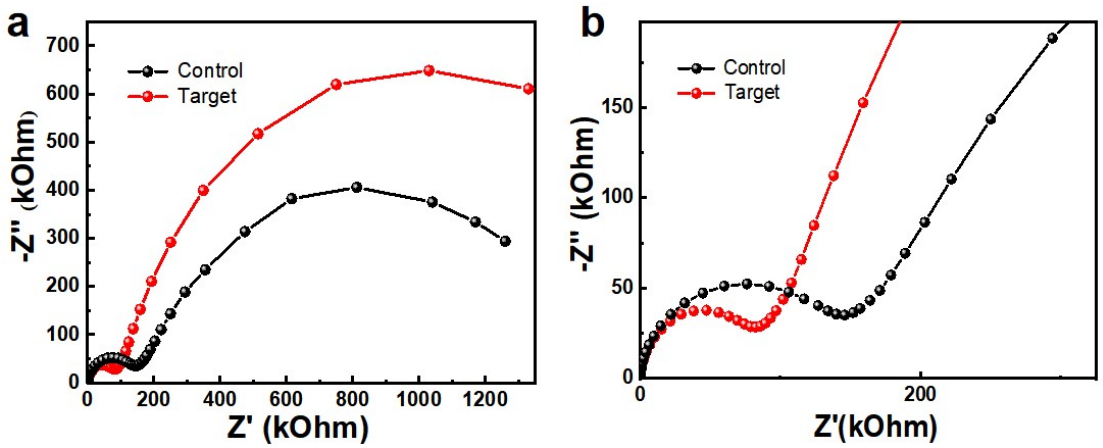

Figure S11. Electrical impedance spectra (EIS) of the control and target equipment (a) and corresponding local enlarged image (b).

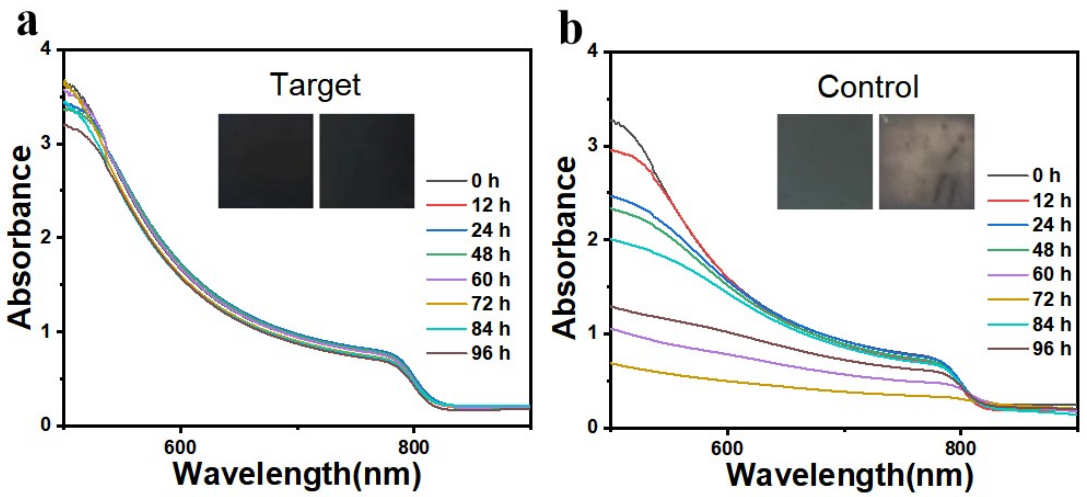

Figure S12. UV-vis absorption spectra of the control (a) and target (b) perovskite films stored in air at 25 °C and ~50% RH. Insets are the photographs of corresponding perovskite films before (left) and after (right) light irradiation for 4 days.

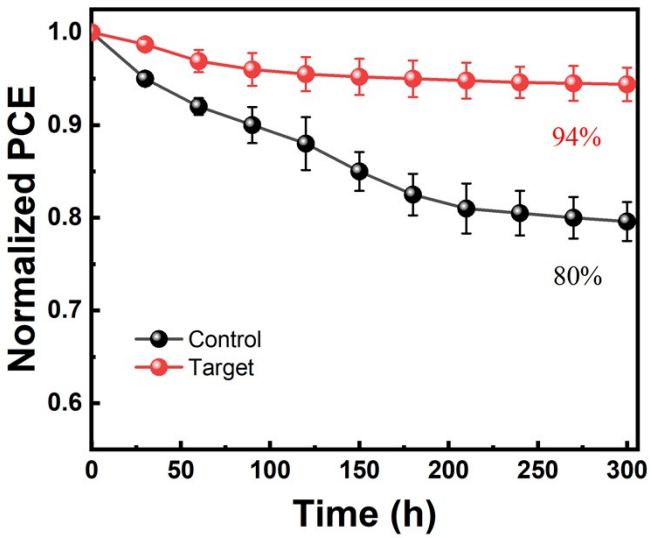

Figure S13. Normalized PCE of the control and target devices without encapsulation, stored at 60 °C in a N_2 atmosphere.

Table S1. Carrier lifetimes for the control and target perovskite films in Figure 3c.

Sample	τ_1 (ns)	A_1	τ_2 (ns)	A_2	τ_{avg} (ns)
Control	577.73	53.86	2601.63	23.14	913.18
Target	600.19	68.44	3508.28	32.74	1559.04

Table S2. The calculated hole mobilities and trap densities for the control and target devices in Figure 3b.

Device	V_{TFL} [V]	Hole N_{trap} [cm^{-3}]
Control	0.36	4.0×10^{15}
Target	0.23	2.6×10^{15}