

Electronic Supplementary Information

Enhanced UV-light stability of organometal halide perovskite solar cells with interface modification and Ultraviolet absorption layer †

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Materials:

Lead iodide (PbI_2 , 99%) was purchased from Sigma-Aldrich; The methylammonium iodide (MAI, 99.5%), 2,2',7,7'-Tetrakis[N,N-di(4-methoxyphenyl)amino]-9,9'-spiro-bifluorene (spiro-OMeTAD, 99.8%), 4-tert-Butylpyridine (96%) and Lithium-bis(trifluoromethanesulfonyl) imide (Li-TFSI, 99.5%) were purchased from Xi'an p-OLED Technology Corp; (3-Aminopropyl) triethoxysilane (KH 550), γ -(2,3-epoxypropoxy)propyltrimethoxysilane (KH 560), 3-Methacryloxypropyltrimethoxysilane (KH 570) and Toluene (anhydrous, 99.9%) were obtained from Sinopharm Chemical Reagent Co.,Ltd. (China); 2-(2H-Benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol (UV-234) was purchased from Guangzhou lihou trading Co.,Ltd; Dimethylacetamide (DMAC, anhydrous, 99.8%), N-Methyl-2-pyrrolidone (NMP, anhydrous, 99.9%) and Titanium tetrachloride (TiCl_4 , anhydrous, 99.5%) and were purchased from Alfa Aesar.

Device fabrication:

Perovskite solar cells were fabricated on fluorine-doped SnO_2 transparent conducting glass substrates. Patterned Fluorine-doped SnO_2 transparent conducting glasses (FTO substrates) were ultrasonically washed with deionized water, acetone and ethanol respectively for 30 min, and then followed by oxygen plasma cleaning for 10 min before use that is similar to our previous work.^[1] The compacted TiO_2 blocking layer is acquired by low-temperature method that FTO substrates were immersed into 200 mM TiCl_4 aqueous solution at 70°C for 60 min. After reaction, the film was washed with deionized water and ethanol respectively, and then drying at 100°C for 60 min. Following, the compacted films were immersed into 3 types of 0.05 mM solutions with silane coupling agent in ethanol for 1 h to introduce a silane layer between interfaces, and then washed with ethanol, dried under a flow of N_2 and annealing at 100°C for 60 min. The perovskite precursor solution was prepared by dissolving 0.2289g of MAI and 0.6639g of PbI_2 for 1.2 M $\text{CH}_3\text{NH}_3\text{PbI}_3$ in 1.2 mL of anhydrous DMAC and NMP (with a volume ratio of 5:1), and then stirring overnight at 70°C. The resulting solutions were filtered with 0.20 μm PTFE filters before use. After the compacted TiO_2 with silicon monomer were transferred into glove box, the prepared perovskite precursor were spin-coated on the surface of the c- TiO_2 with 1000 rpm for 20 s, 5000 rpm for 50 s, while the progress goes to 8-10 s of spin-coating at 5000 rpm, 45 μL of toluene was quickly dropped onto the substrates within 2s and then the substrate were annealed at 100°C for 5 minutes. Subsequently, after cooling to room temperature, a volume of 10 μL spiro-MeOTAD solution was spin-coated onto the surface of perovskite films at 5000 rpm for 30s to form the hole transport layer, where the solution of spiro-MeOTAD prepared is followed the corresponding literature. First, 520 mg of Li-TFSI dissolved in 1 mL acetonitrile for stirring was prepared before use, and then 72.3 mg spiro-MeOTAD along with 28.8 μL 4-tert-butylpyridine and 17.5 μL Li-TFSI were dissolved in 1 mL chlorobenzene for stirring. Following, 80 nm thick gold electrodes were deposited by thermal evaporation at 1.0×10^{-4} Pa on the top of spiro-MeOTAD to fabricate planar perovskite solar cells with a 0.07 cm^2 shadow mask. Both the perovskite absorber and hole transport layer was deposited in a glove box with the protect of N_2 . Finally, a UV-absorber layer was fabricated through dissolving 250 mg UV-234 in chlorobenzene that a volume of 25 μL solution was spin-coated with optimal rotation rate at 2850 rpm for 30 s.

Characterizations:

Field emission scanning electron microscope (FESEM, Philips XL30 FEG) is used to characterize the surface and cross-sectional morphology of different perovskite films on c- TiO_2 and c- TiO_2 /SCA. The Fourier Transform Infrared Spectrometer (FT-IR, Nicolet IS10, Thermo Scientific) are obtained to characterize the functional group of silane coupling agent to distinguish whether the SCA has been introduced onto the compacted TiO_2 layer. For different c- TiO_2 /SCA was performed at the wavenumbers of 4000 - 500 cm^{-1} . The crystal grain size, structure and stability of the films are performed by X-ray diffraction (XRD) analysis with $\text{Cu K}\alpha$ radiation (D/max 2500 PC, Rigaku Corporation, Japan; 2 theta, $\lambda = 0.1542$ nm) at 40 kV. Atomic force microscope (AFM) was carried out using VEECO Nano Man VS Scanning Probe Microscope to investigate the effects of SCA on $\text{CH}_3\text{NH}_3\text{PbI}_3$ films and TiO_2 layers.

The time-resolved photoluminescence (TRPL) decay is performed on a LifeSpec II fluorescent spectrometer (Hamamatsu, Edinburgh, UK). The photovoltaic property of Pero-SCs are measured employing a Keithley Model 2400 multisource meter (Cleveland, OH, USA) under illumination of 1 sun with intensity of 100 mW cm^{-2} (AM 1.5G), a solar simulator (500 W Xe lamp) (ORIEL Solar 3A-94023A, America) is employed to provide simulated sunlight . For the UV-aging stability test of Pero-SCs, the devices without any protection were illuminated under UV light with intensity of 4.0 mW cm^{-2} emitted by High-pressure mercury lamp, and were tested every 4 h. All the above measurements were performed in ambient environment without any encapsulation.

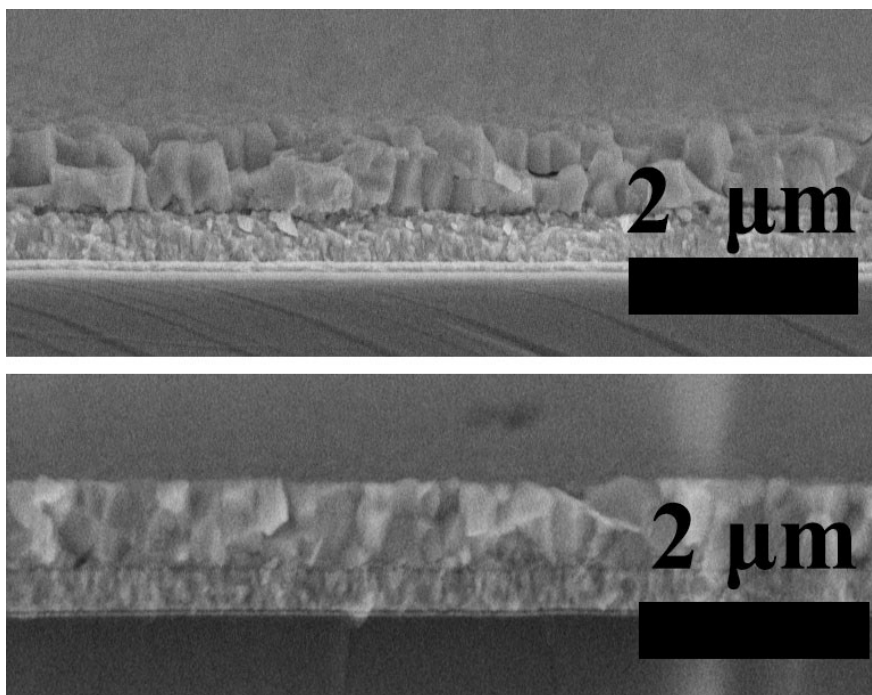


Fig. S1 Cross-sectional SEM images of the perovskite solar cells FTO/c-TiO₂/KH 570/CH₃NH₃PbI₃

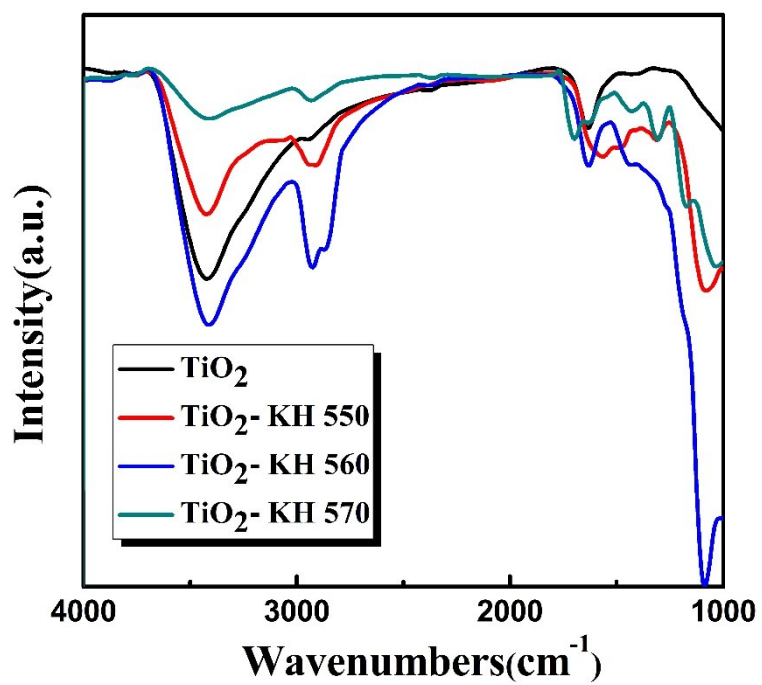


Fig. S2 FT-IR spectra of three types of SCM on c-TiO₂ substrates.

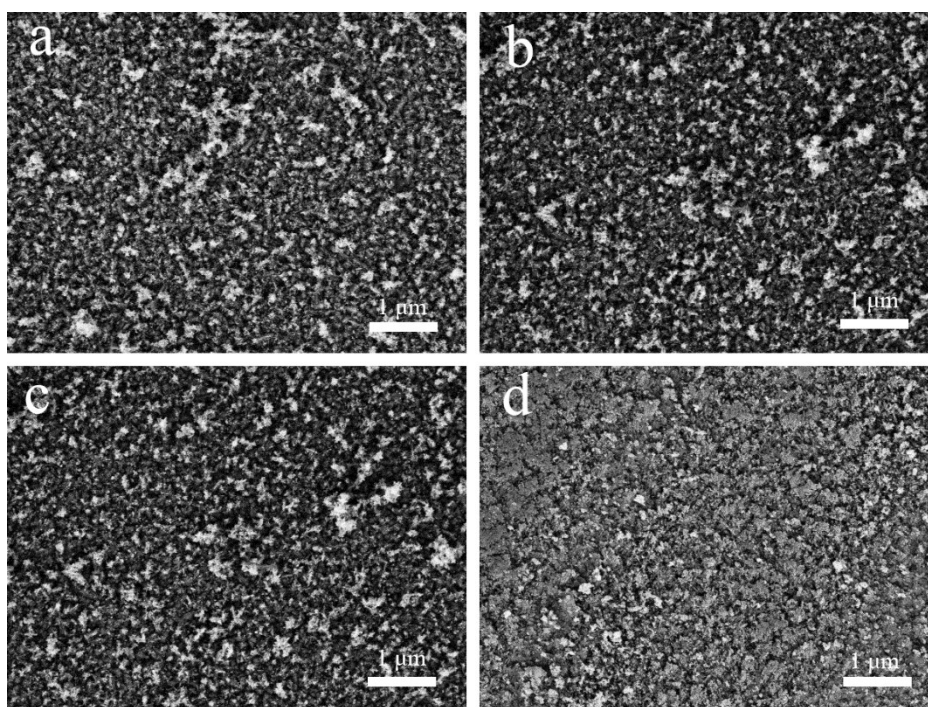


Fig. S3 SEM images of c-TiO₂ with different modification of SCA. a) c-TiO₂ film, b) c-TiO₂/KH 550 film, c) c-TiO₂/KH 560 film, d) c-TiO₂/KH 570 film.

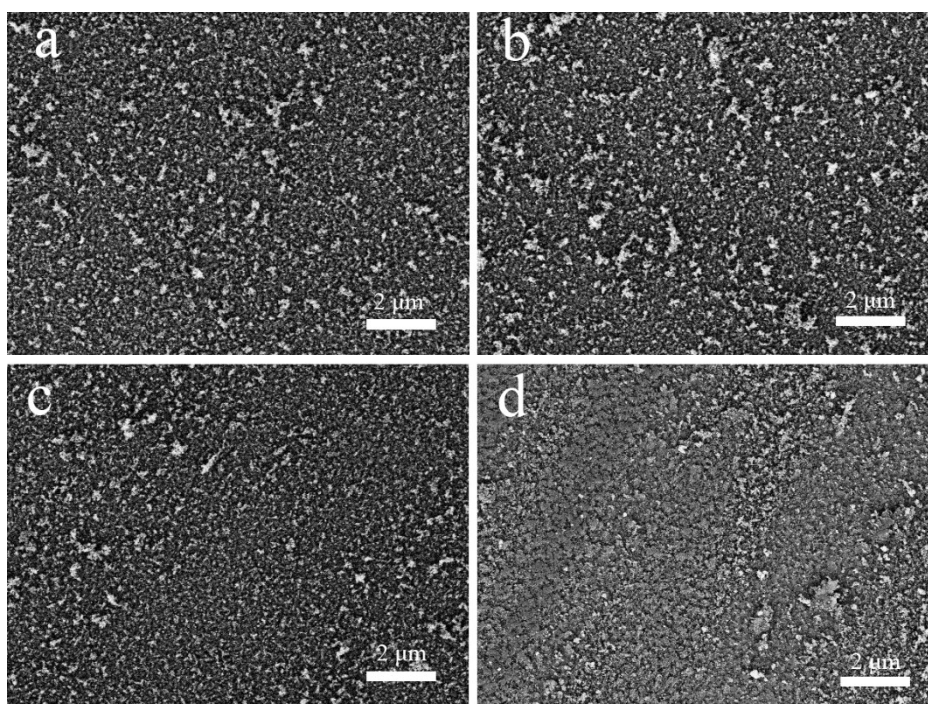


Fig. S4 SEM image (low-magnification 5.0 K) of c-TiO₂ with different modification of SCA. a) c-TiO₂ film, b) c-TiO₂/KH 550 film, c) c-TiO₂/KH 560 film, d) c-TiO₂/KH 570 film.

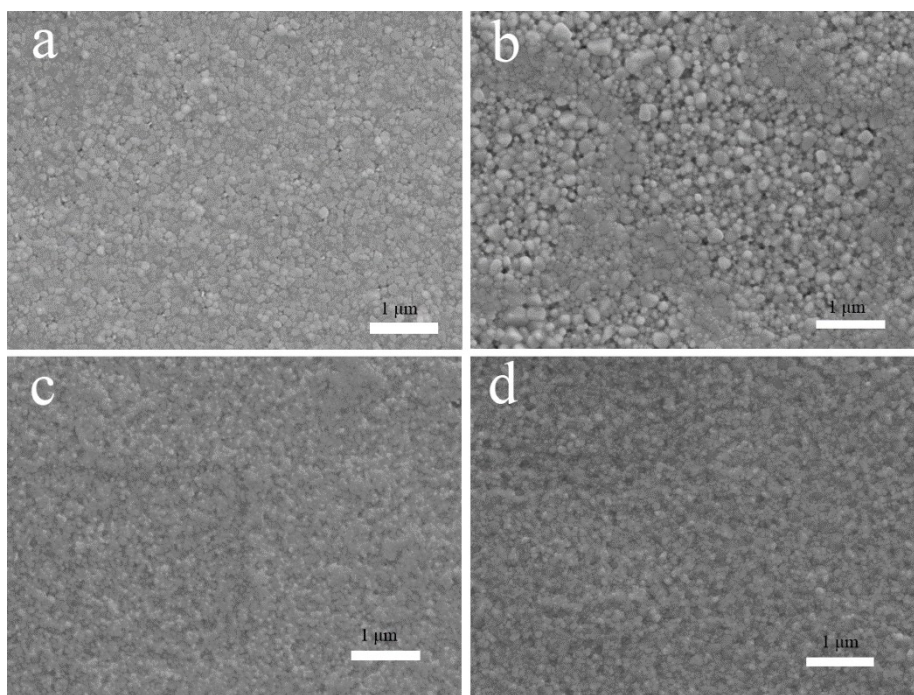


Fig. S5 SEM images (low-magnification 10.0 K) of perovskite films with different modification of SCA. a) pristine, b) KH 550, c) KH 560, d) KH 570.

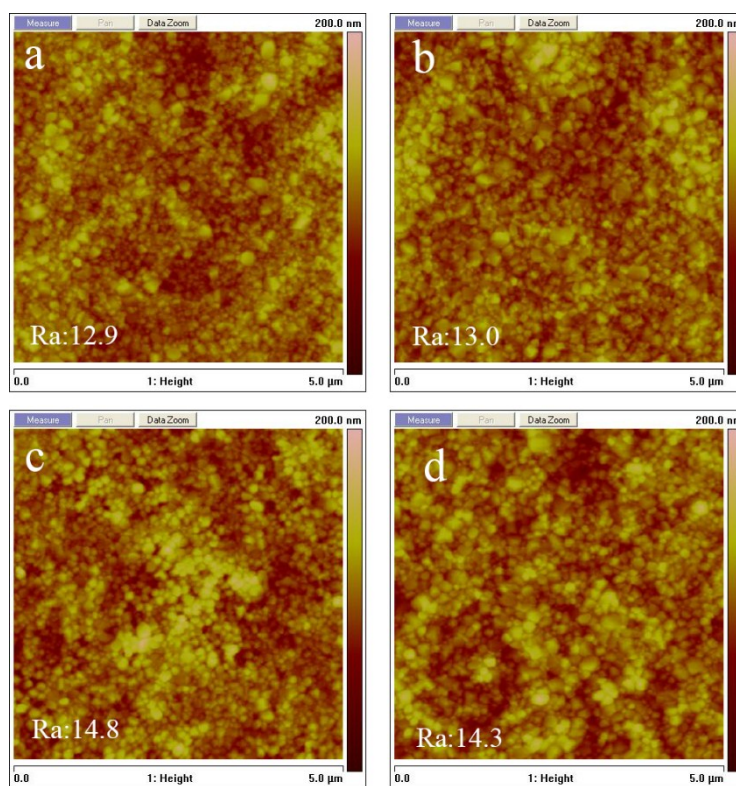


Fig. S6 AFM image of perovskite films with different modification of SCA. a) c-TiO₂ film, b) c-TiO₂/KH 550 film, c) c-TiO₂/KH 560 film, d) c-TiO₂/KH 570 film.

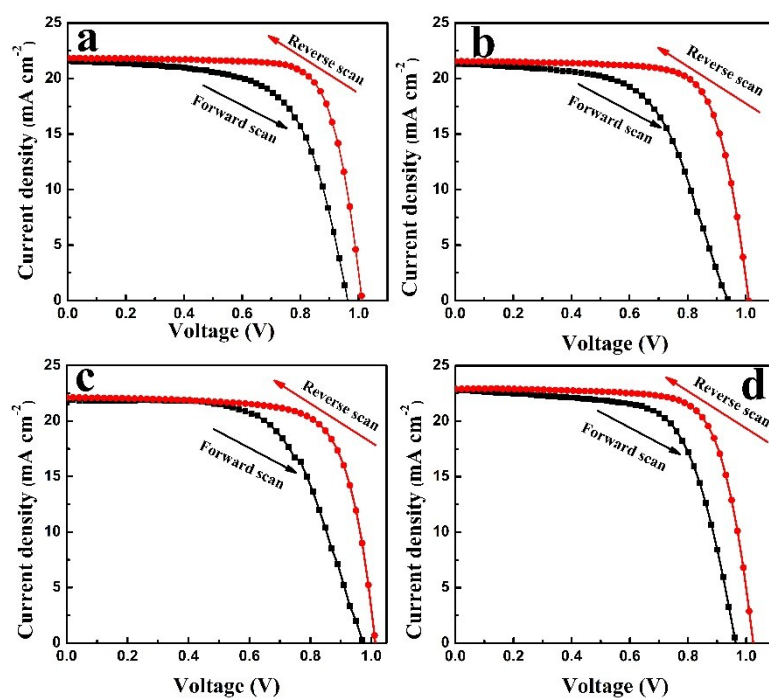


Fig. S7 J - V characteristics of devices with different modification of SCA under both reverse and forward scan directions. a) pristine, b) KH 550, c) KH 560, d) KH 570.

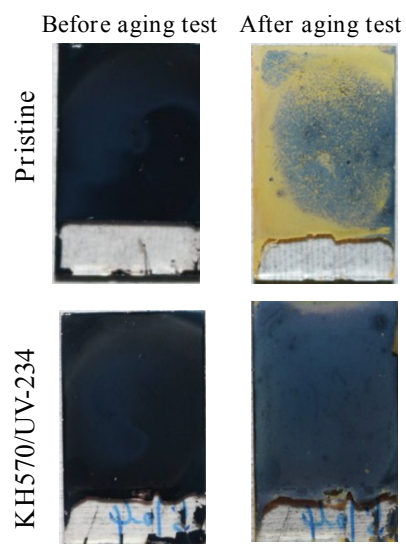


Fig. S8 Digital photos of pristine perovskite film and $\text{CH}_3\text{NH}_3\text{PbI}_3$ films with the compounding effect of KH570 and UV-234 before and after UV-aging stability test.

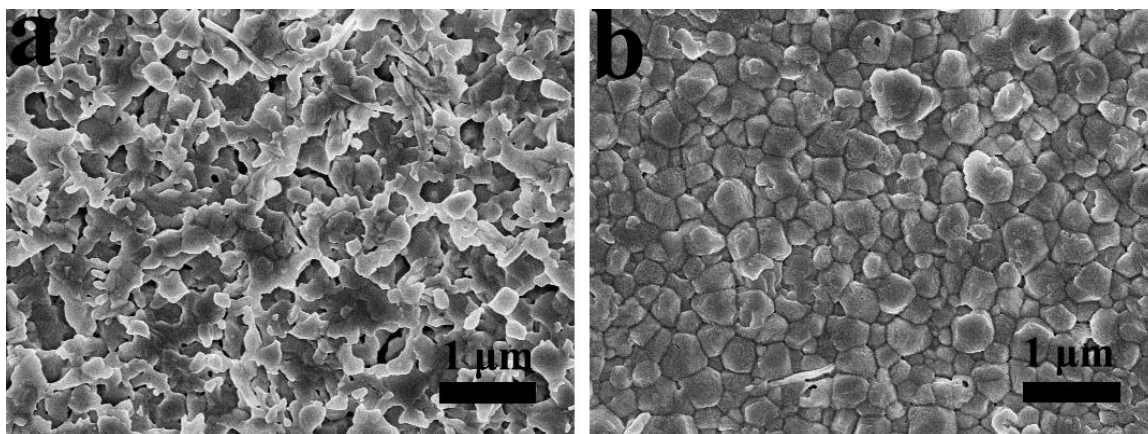


Fig. S9 SEM image (low-magnification 5.0 K) of perovskite films after aging test. a) Pristine, (b) with interface modification and UV-absorber layer

- [1] Y. Sun, Y. Wu, X. Fang, L. Xu, Z. Ma, Y. Lu, W.-H. Zhang, Q. Yu, N. Yuan, J. Ding, *J. Mater. Chem. A*. **2017**, *5*, 1374-1379.