Supporting Information

Air-Processed FA-Cs Perovskite Scalable Films without Pb^0 Defects for Efficient Inverted Photovoltaic Modules

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Figure S1 Particle size statistical graph corresponding to the SEM images. The doping concentration of $(CH_3)_3SI$ are (a) 0, (b) 0.1, (c) 0.2, (d) 0.4, (e) 0.6 mg/mL.

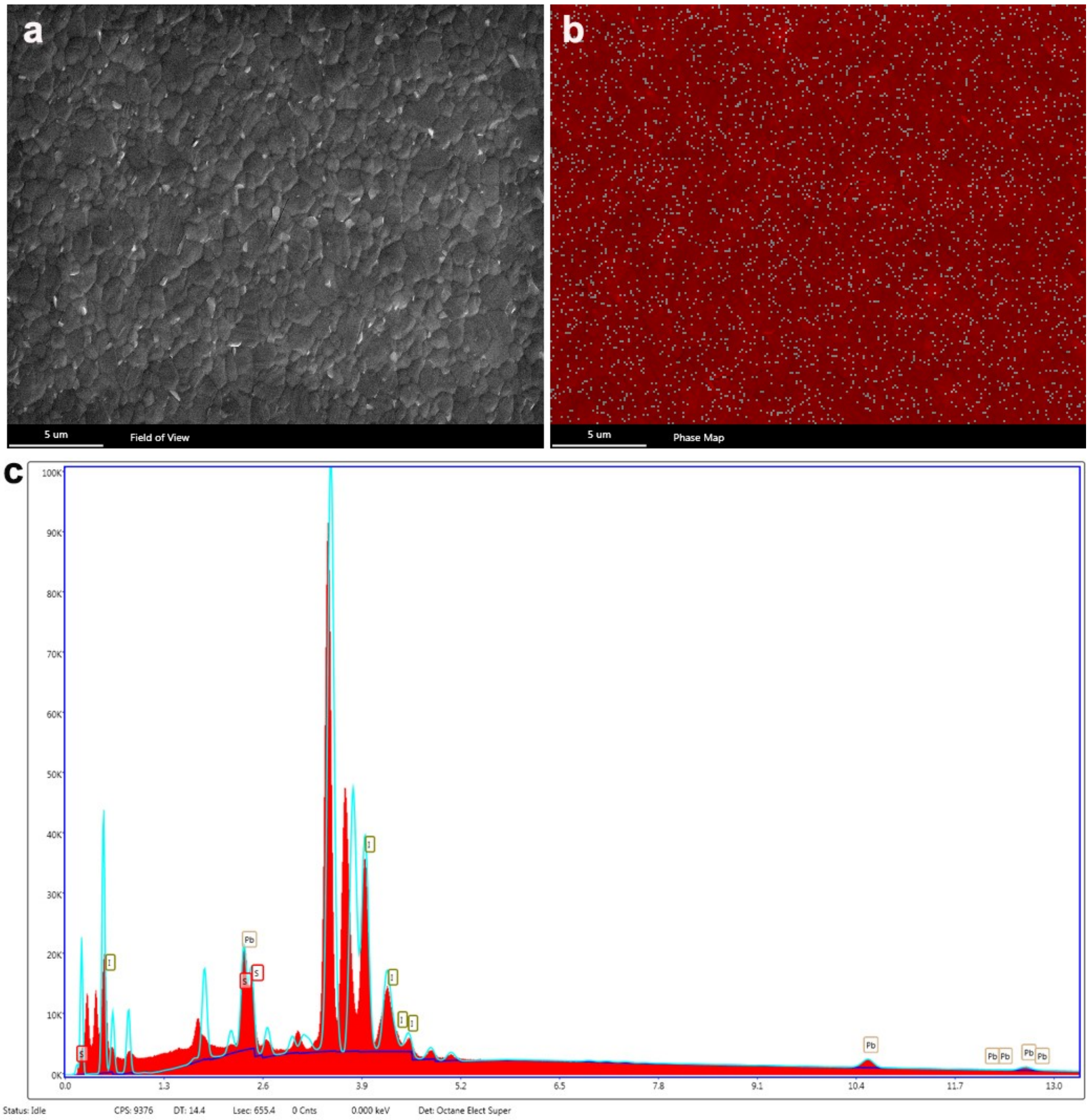

Figure S2 (a) SEM image of the perovskite film with $(CH_3)_3SI$ additive, revealing a dense grain structure with distinct grain boundary outlines. (b) The signal of S element of the red bright spots represent. The red signal uniformly covers the entire surface, and notably, exhibits relatively higher intensity at the grain boundaries. (c) The energy-dispersive X-ray spectroscopy (EDS) spectrum. The characteristic peaks of S directly confirming the successful incorporation of sulfur into the perovskite film. The enrichment of sulfur at the grain boundaries and surface demonstrates that $(CH_3)_3SI$ can effectively passivate grain boundary defects and suppress ion migration, thereby enhancing the power conversion efficiency and long-term stability of the corresponding devices.

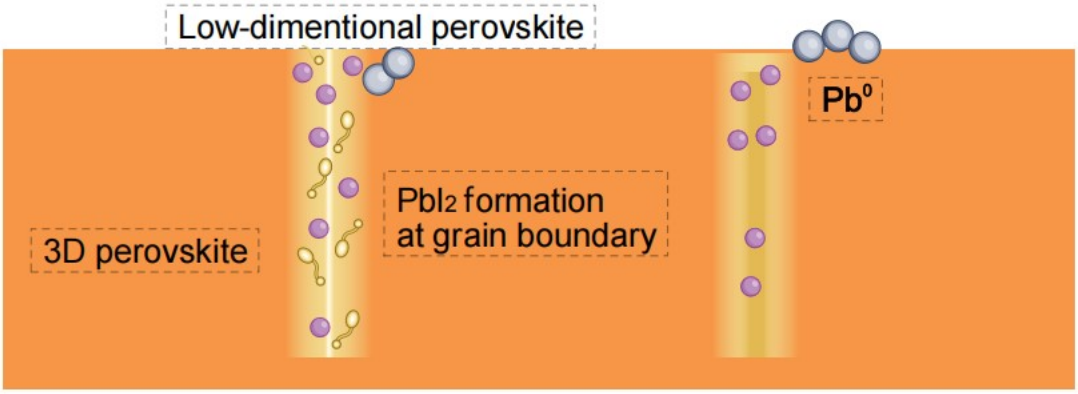

Figure S3 Schematic diagram of a general rule at perovskite grain boundaries. During the formation of perovskite films, light-sensitive PbI_2 tends to form at grain boundaries, and PbI_2 further generates deep-level defect Pb^0. Therefore, eliminating PbI_2 can effectively reduce the defect density.

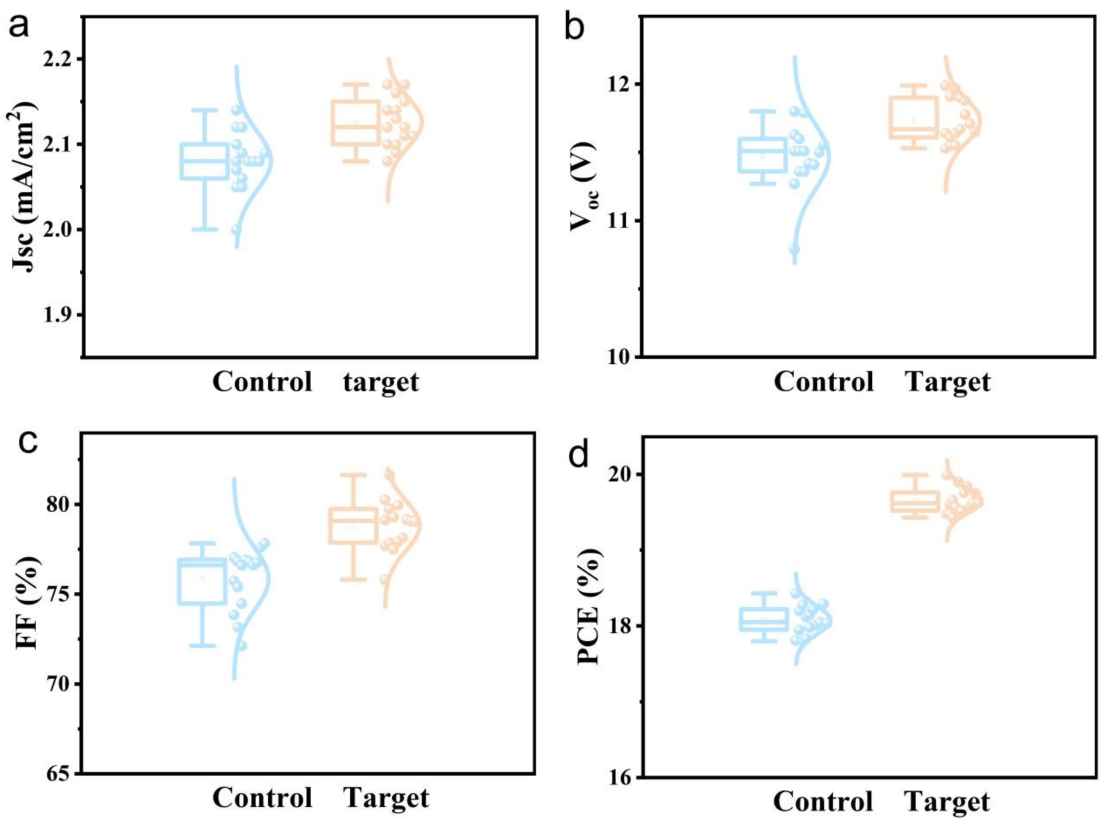

Figure S4 Statistical parameters of control and target modules with the 0.2 mg/mL $(CH_3)_3SI$ additive,including (a)J_{SC}, (b)V_{OC}, (c) FF, and (d) PCE.

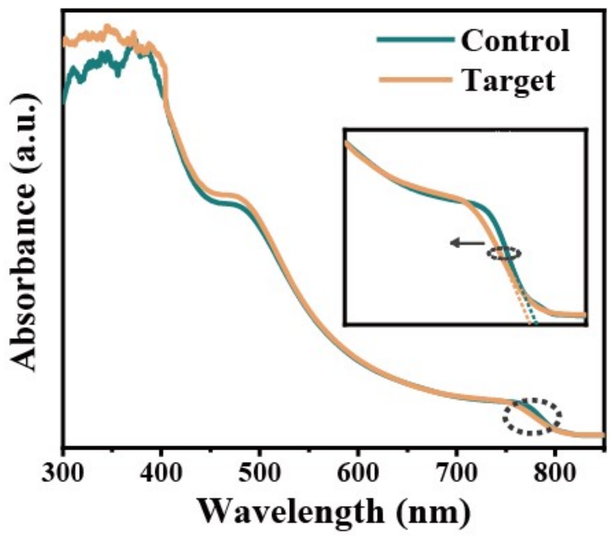

Figure S5 UV-visible absorption spectrum. The inset is enlarged region.

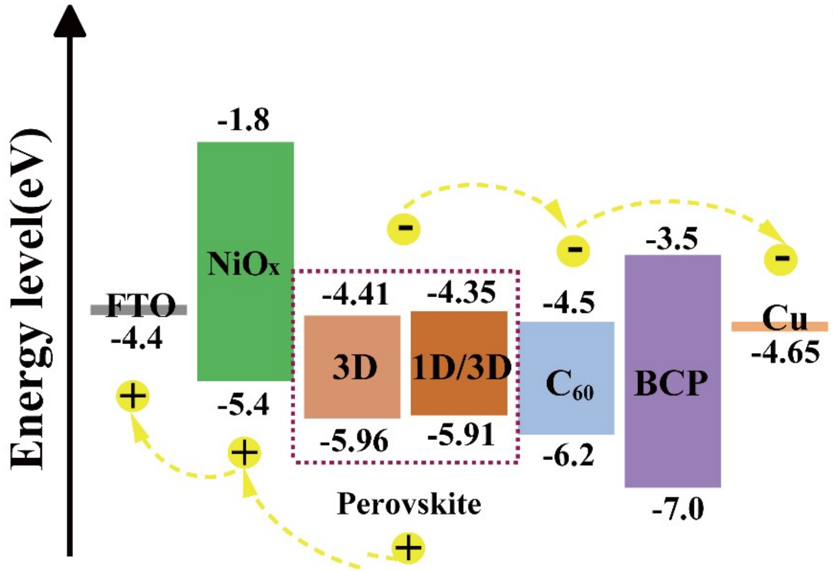

Figure S6 Energy-level diagrams of the module devices.

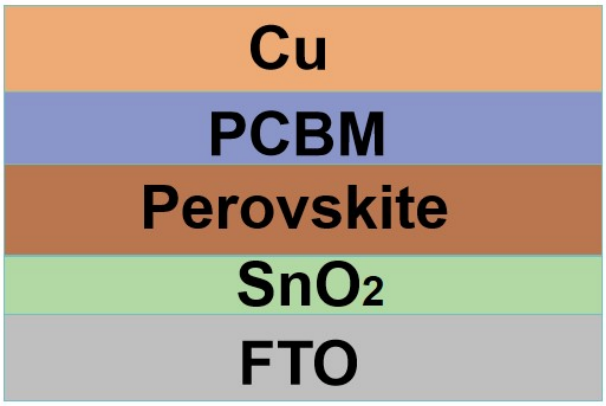

Figure S7 Schematic diagram of "FTO/SnO_2/perovskite/PCBM/Cu" structure used to measure the space-charge-limited current (SCLC).