

Supplementary information

Interpenetrating Interfaces for Efficient Perovskite Solar Cells with High Operational Stability and Mechanical Robustness

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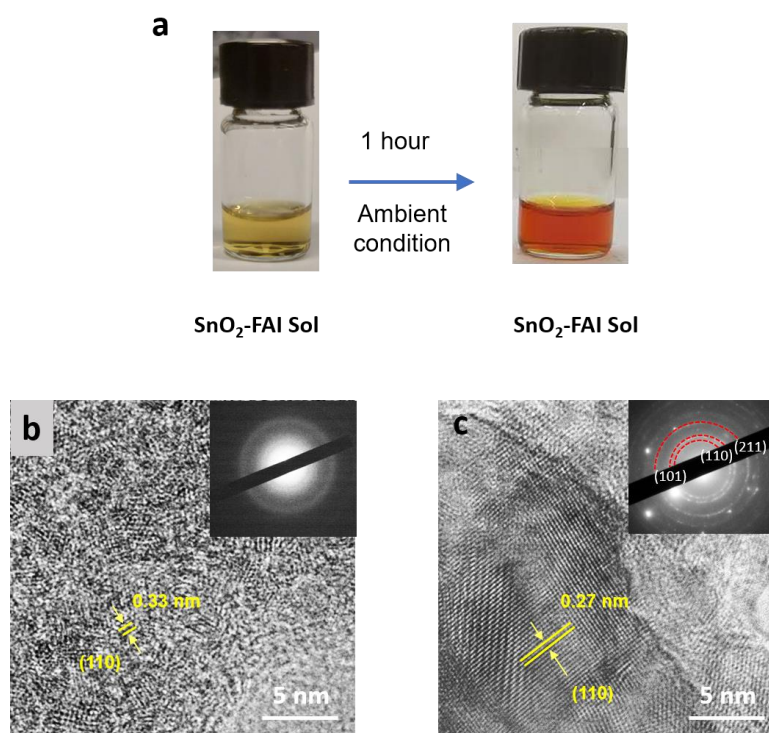
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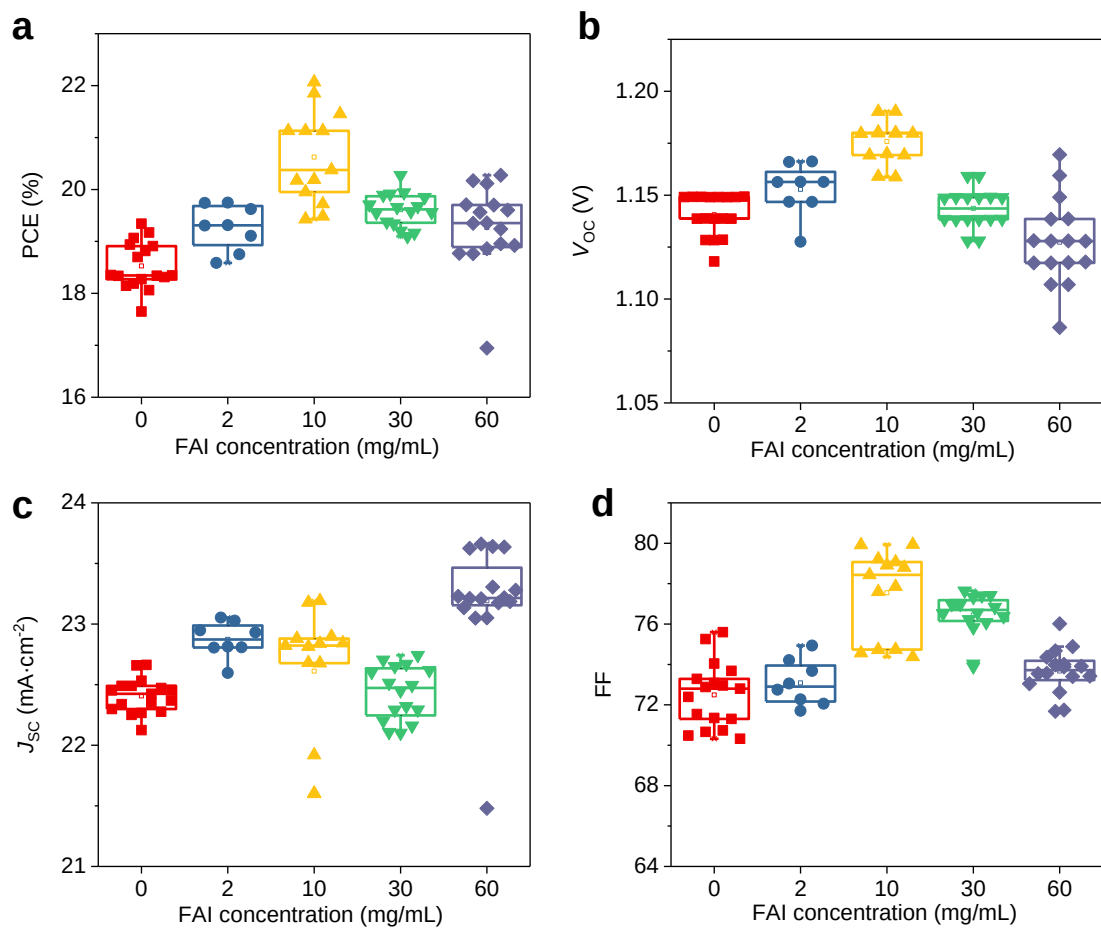


Supplementary Figure 1. **SnO₂ nanocrystals characteristics.** **a** Images of FI-SnO₂ (10 mg/mL) colloids: fresh (left) and stored under ambient condition for 1 h (right). HRTEM image of SnO₂ nanocrystallines scraped from **b** the pristine SnO₂ ETL, and **c** the FI-SnO₂ ETL. Insert: corresponding selected-area electron diffraction patterns.

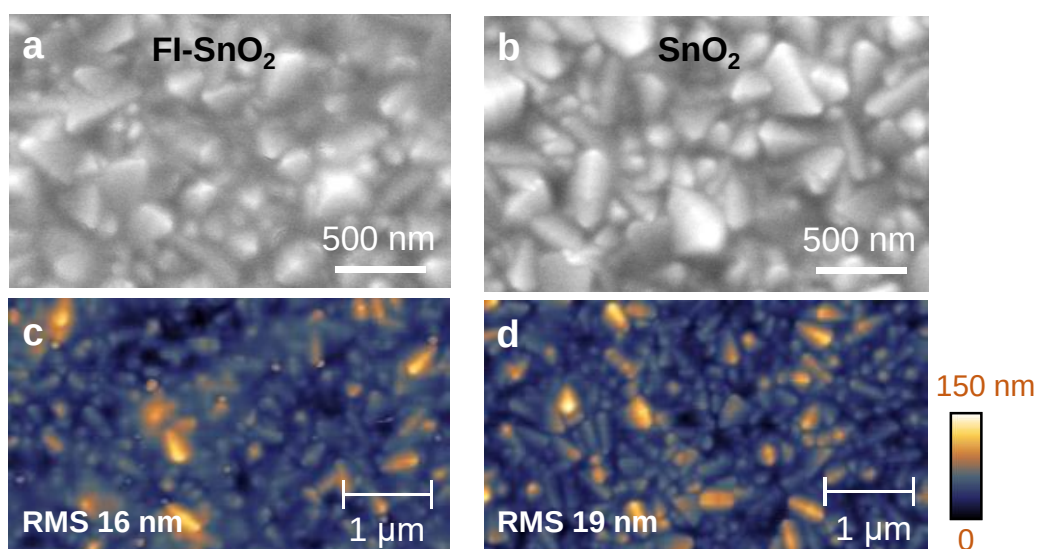
The re-growth mechanism of the SnO₂ nanocrystals. When the FI-SnO₂ colloid placed under ambient condition for a longer time (~ 1 hour), the color changed from light brown to dark brown, indicating the formation of I₂, following the chemical reaction below:



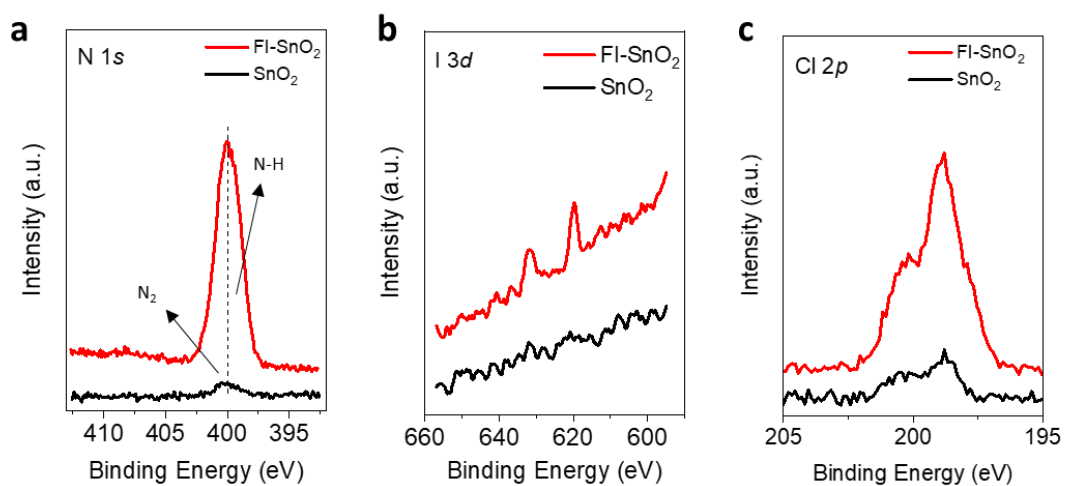
the produced OH⁻ will promote further hydrolysis of -OR on the surface of SnO₂, triggering condensation and re-crystallization of SnO₂ nanocrystals (*Adv. Energy Mater.* 2019, 9, 1900834).



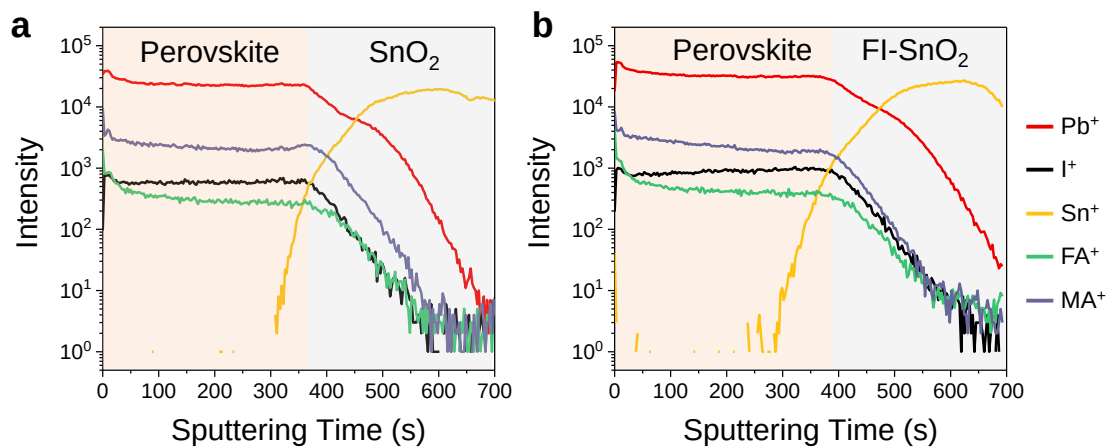
Supplementary Figure 2. **Optimization of FAI concentration in SnO₂ colloidal.** Statistics of the photovoltaic parameters: **a** PCE, **b** V_{oc} , **c** J_{sc} , and **d** FF of the devices on the ETLs from SnO₂ colloidal with different FAI concentrations.



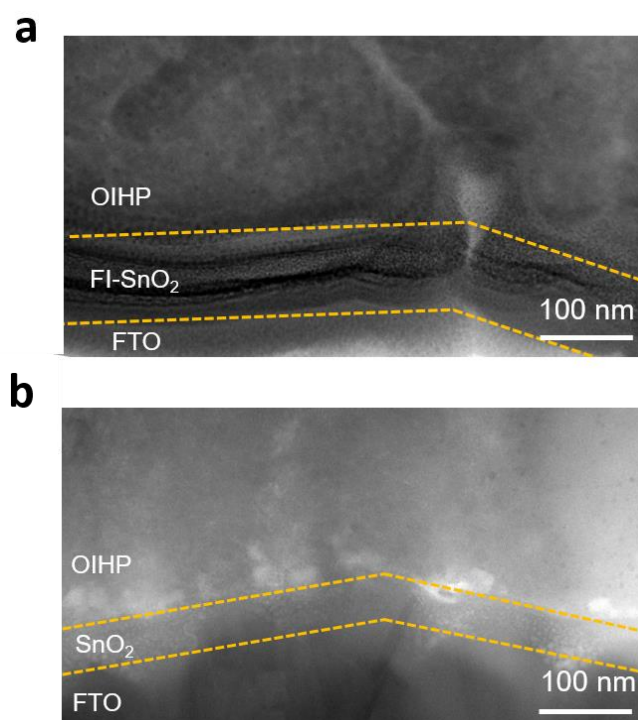
Supplementary Figure 3. **Surface morphology of ETLs.** **a, b** SEM images and **c, d** AFM mappings of the FI-SnO₂ (left) and SnO₂ (right) ETLs on FTO substrates.



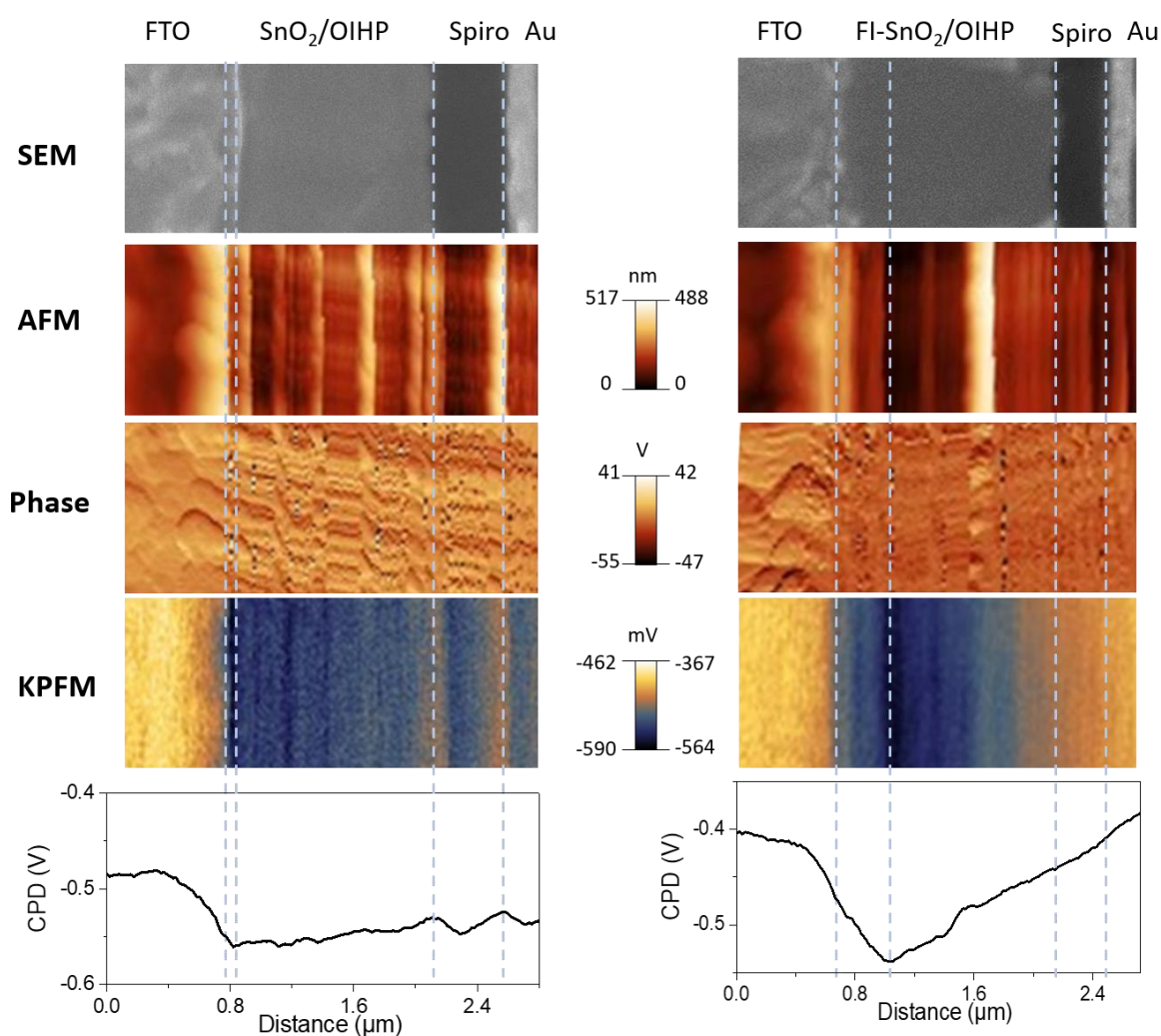
Supplementary Figure 4. **Composition analysis of ETLs.** XPS spectra of **a** N 1s, **b** I 3d and **c** Cl 2p for FI-SnO₂ and SnO₂ ETLs.



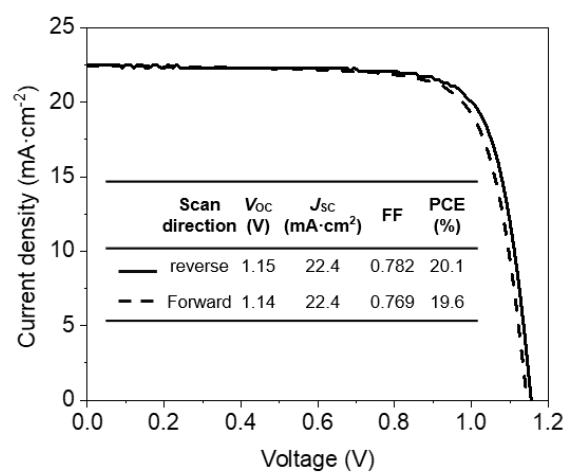
Supplementary Figure 5. **Structure characterization of OIHP/ETL interfaces.** The full ToF-SIMS elemental depth profiles: (a) OIHP/SnO₂ ETL; (b) OIHP/FI-SnO₂ ETL.



Supplementary Figure 6. **Microstructural characterization of the OIHP/ETL interface.** Cross-sectional STEM images of OIHP films on, **a** the FI-SnO₂ ETL and **b** the pristine SnO₂ ETL.



Supplementary Figure 7. **Nanoscale correlated characterization of morphology and electronic properties.** From top to bottom: SEM images, topographic AFM images, phase images, KPFM images and contact potential difference (CPD) profiles of the SnO_2/OIHP (left column) and the $\text{FI-SnO}_2/\text{OIHP}$ (right column) devices.



Supplementary Figure 8. **Photocurrent Hysteresis characteristics.** *J-V* curves (forward and reverse scans) of the champion flexible PSCs based on the FI-SnO₂ ETL.