

## Supporting Information

### Printable Mesoscopic Perovskite Solar Cells with Performance Tuning via Trifluoroacetamide

Xing Li,<sup>‡a</sup> Pengyu Wang,<sup>‡a</sup> Rongrong Guo,<sup>‡a</sup> Yiwen Chen,<sup>a</sup> Changqing Chen,<sup>a</sup>  
Weihuang Yang,<sup>a</sup> Qin Zeng,<sup>a</sup> Chao Ye,<sup>a</sup> Yu Huang<sup>\*a</sup>, and Jian Zhang<sup>\*a</sup>

<sup>a</sup> School of Materials Science and Engineering, School of Optoelectronic Engineering,  
Engineering Research Center of Electronic Information Materials and Devices  
(Ministry of Education), Guangxi Key Laboratory of Information Materials, Guilin  
University of Electronic Technology Guilin, 541004, China.

\* Corresponding author: Yu Huang, and Jian Zhang.

<sup>‡</sup> These authors contribute equally to this work.

E-mail: [huangyu@guet.edu.cn](mailto:huangyu@guet.edu.cn) (Y. Huang), [jianzhang@guet.edu.cn](mailto:jianzhang@guet.edu.cn) (J. Zhang)

## Experimental Section

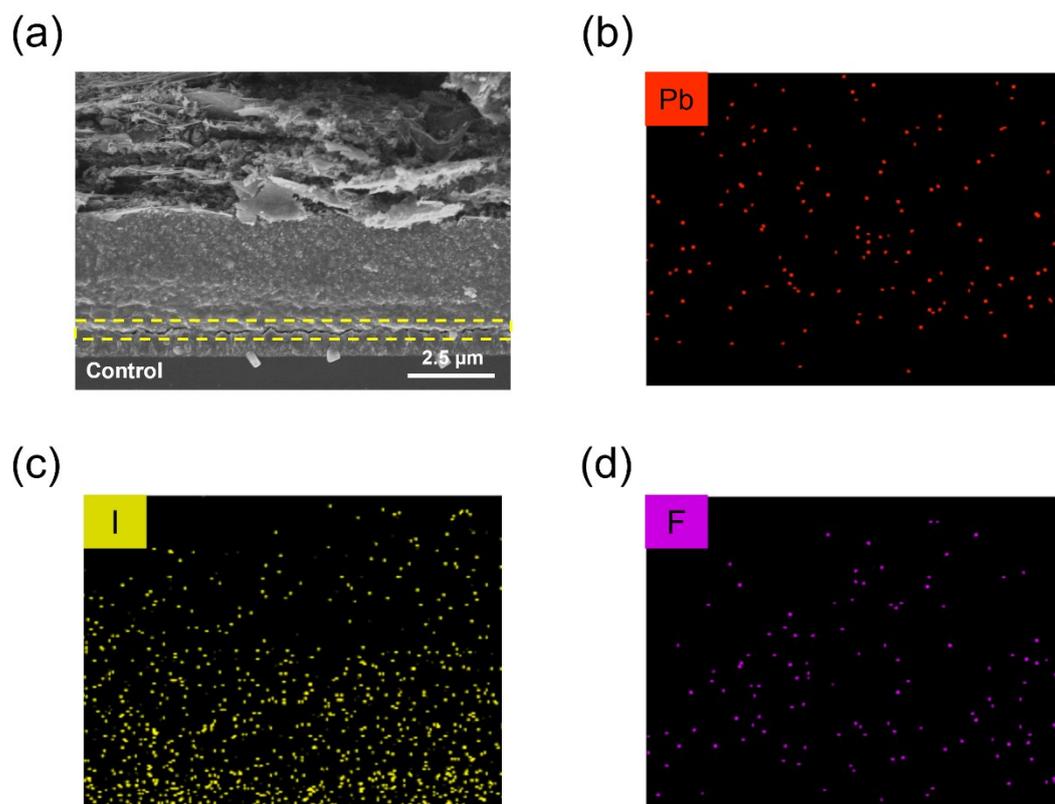
**Materials:** Cesium iodide (CsI, 99%), methylammonium chloride (MACl, >99%), methylamine iodine (MAI, 99.5%), formamidinium iodide (FAI, 99.5%), and lead (II) iodide (PbI<sub>2</sub>, 99.99%) were purchased from Xi'an P-OLED Company. The supplier of trifluoroacetamide (TFAA, 98%) was Beijing Innochem Technology Co., Ltd. Sigma-Aldrich provided the Titanium diisopropoxide bis(acetylacetonate) (75 wt.% in IPA), N, N-dimethylformamide (DMF, 99.8%), and dimethyl sulfoxide (DMSO, 99.8%). Wonder Solar Co., Ltd. supplied the carbon and ZrO<sub>2</sub> slurries, as well as the fluorine doped tin oxide conducting glass (FTO). Without any additional purification, all of these items were used just as they were received.

**Precursor Preparation:** A volume of 0.8 mL of DMF/DMSO (4:1) was used to mix CsI (0.0130 g, 0.05 mmol), MACl (0.0135 g, 0.2 mmol), MAI (0.0239 g, 0.15 mmol), FAI (0.1376 g, 0.8 mmol), and PbI<sub>2</sub> (0.4610 g, 1 mmol). After that, different concentrations of TFAA (1%, 2%, and 3% mol/L) were added to this solution. For 1 h, the prepared precursor solution was stirred constantly at 55 °C.

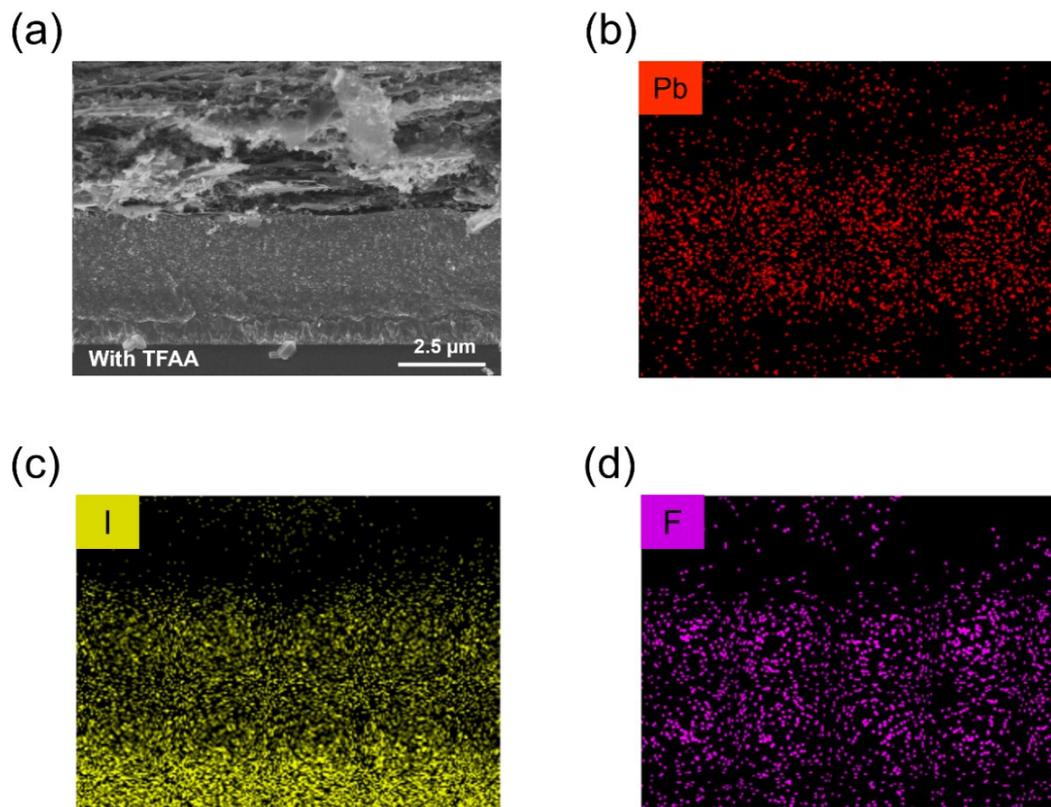
**Device Fabrication:** The desired electrode pattern was first created by laser etching FTO glass. After that, the glass was cleaned in an ultrasonic cleaner for 10 minutes each with detergent, deionized water, and ethanol. Following the cleaning process, a compact TiO<sub>2</sub> layer was deposited onto the FTO substrate using spray pyrolysis with a titanium isopropoxide bis(acetylacetonate) solution at 450 °C. Subsequently, a mesoporous TiO<sub>2</sub> layer was screen-printed onto the compact TiO<sub>2</sub> layer and then annealed at 500 °C for 40 minutes. When the TiO<sub>2</sub> layer was annealed for 40 minutes at 400 °C, the mesoporous ZrO<sub>2</sub> and porous carbon layers were screen-printed on top. The precursor solution was pipetted onto the mesoporous scaffolds and allowed to cool to room temperature before being annealed for 18 h at 57°C.

**Characterization:** A Keithley 2400 source meter was used to measure the current density-voltage (*J-V*) curves for each device under AM 1.5G illumination with an intensity of 100 mW/cm<sup>2</sup>. The effective area was 0.1 cm<sup>2</sup>, and measurements were made at a scan rate of 100 mV/s throughout a voltage range of -1 V to 1.2 V. A Bruker D8 Advance X-ray diffractometer operating at 40 kV and 40 mA was used to study the crystallization of the perovskite films. An AXIS-ULTRA DLD600W spectrometer (Kratos Co.) was employed to get the results of ultraviolet photoelectron spectroscopy (UPS) and X-ray photoelectron spectroscopy (XPS). Scanning electron microscopy (FEI, Quanta FEG 450, USA) provided imaging views of the perovskite films in both

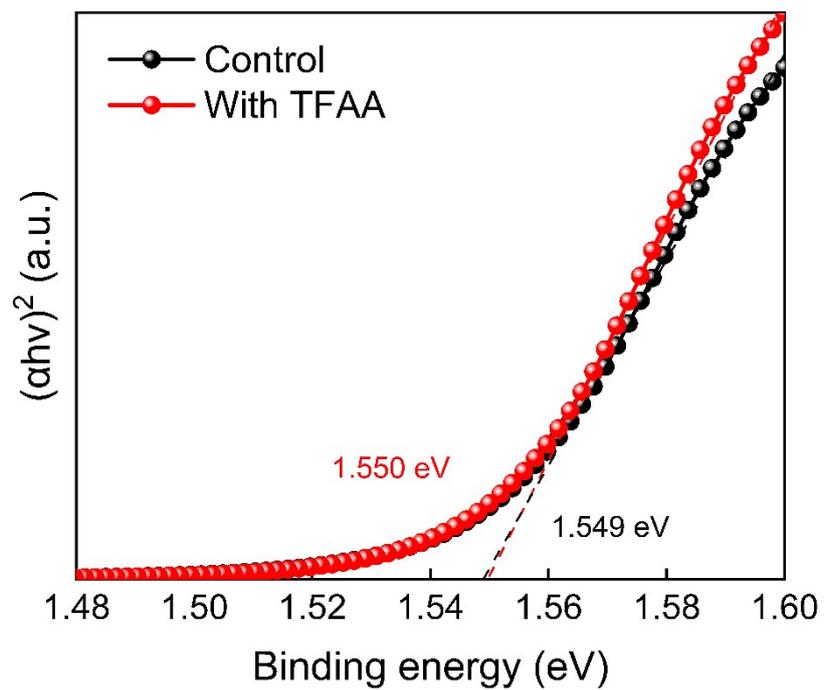
cross-section and top view. A SolidSpec-3700 UV-vis spectrometer was utilized to identify UV-vis absorption spectra in the 350–850 nm range. External quantum efficiency (EQE) was measured using a QE-R measurement equipment (Enlitech, Taiwan). Time-resolved photoluminescence (TRPL) and steady-state photoluminescence (PL) spectra were recorded utilising the fluorescence spectrometer (Edinburgh, FS 5, UK). Capacitance-voltage curves and electrochemical impedance spectroscopy (EIS) were measured at -0.30 V with a CHI660E electrochemical workstation (China). In tapping mode, a Kelvin probe force microscope (Bruker, Multimode 8, Germany) was used to measure the films' surface potential. Fourier-transform infrared (FTIR) spectroscopy was obtained with a Nicolet 6700 spectrometer purchased from Thermo Fisher in the United States.



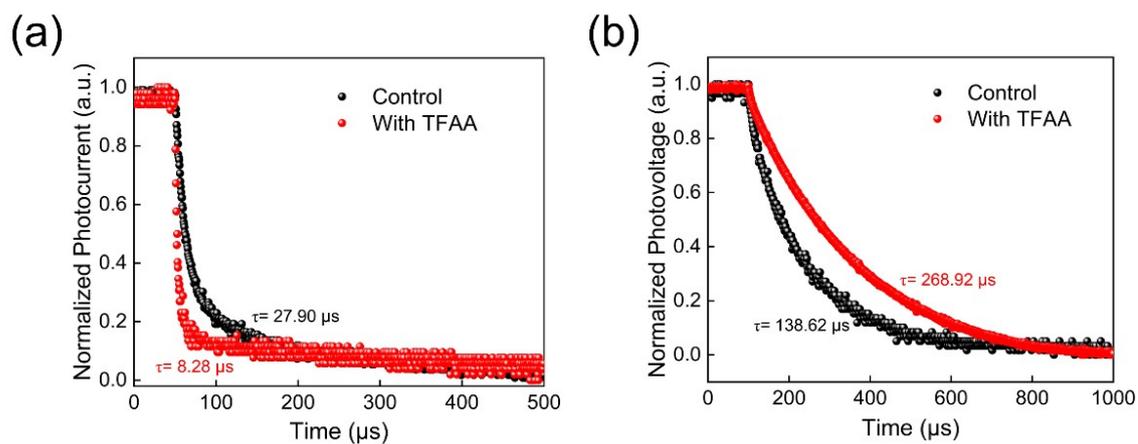
**Figure S1.** EDS mapping (Pb, I, and F element distribution) of the p-MPSCs fabricated (b, c, d) without TFAA.



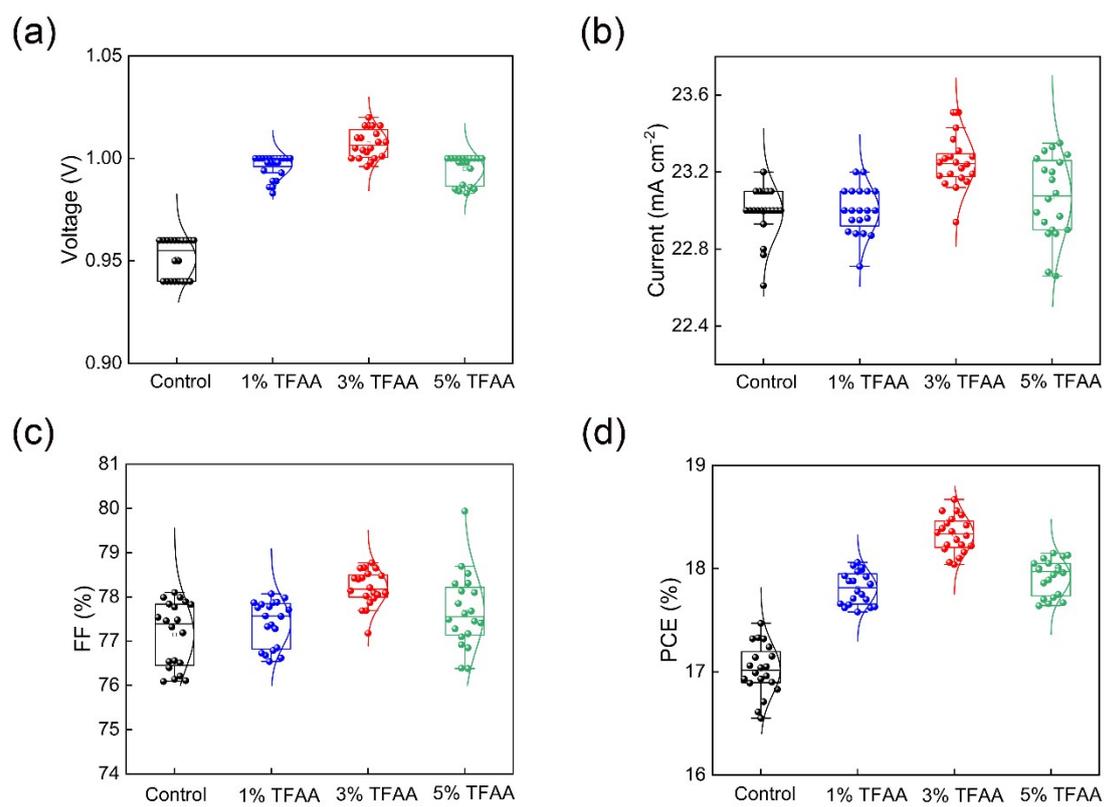
**Figure S2.** EDS mapping (Pb, I, and F element distribution) of the p-MPSCs fabricated (b, c, d) with TFAA.



**Figure S3.** plot of  $\alpha$  versus binding energy fitted by UV-vis absorption spectra.



**Figure S4.** Plot of transient photocurrent vs. transient photovoltage with and without TFAA.



**Figure S5.** PV parameters ( $V_{OC}$ ,  $J_{SC}$ , FF, and PCE) for p-MPSCs without and with TFAA.

**Table S1.** TRPL fitting parameters and calculated average lifetimes on the ZrO<sub>2</sub> substrate.

	$\tau_1$ (ns)	$A_1$	$\tau_2$ (ns)	$A_2$	$\tau_{ave}$ (ns)
W/O TFAA	2.06	556.75	23.28	245.78	25.20
With TFAA	2.56	515.60	22.26	279.92	28.75

**Table S2.** Photovoltaic parameters of the devices with various concentrations of TFAA.

	$V_{oc}$ (V)	$J_{sc}$ (mA cm <sup>-2</sup> )	FF (%)	PCE (%)
0 mol%	0.960±0.010	23.14±0.34	77.72±0.27	17.24±0.23 (17.47)
1 mol%	1.000±0.010	22.98±0.17	77.84±0.18	17.95±0.11 (18.06)
3 mol%	1.010±0.010	23.15±0.90	77.83±0.65	18.46±0.24 (18.67)
5 mol%	1.010±0.010	22.83±0.15	78.03±1.17	18.01±0.10 (18.15)