Supporting Materials

Junction Quality of SnO_2-Based Perovskite Solar Cells Investigated by Nanometer-Scale Electrical Potential Profiling

Chuanxiao Xiao,[1,2†] Changlei Wang,[3†] Weijun Ke,[3] Brian P. Gorman,[2] Jichun Ye,[4] Chun-sheng Jiang,[1*] Yanfa Yan,[3*] and Mowafak M. Al-Jassim[1]

[1] National Renewable Energy Laboratory, Golden, CO 80401 USA

[2] Colorado School of Mines, Golden, CO 80401 USA

[3] The University of Toledo, Toledo, OH 43606 USA

[4] Ningbo Institute of Industrial Technology, Chinese Academy of Science, Ningbo, Zhejiang Province 315201 China

[†] These authors contributed equally to this work

[*] Correspondence should be addressed to: chun.sheng.jiang@nrel.gov; yanfa.yan@utoledo.edu.

How we cleaved the sample to expose the cross-section:

The substrate was scribed on film side, but out of the device region, then we cleave the glass from the film side, without touching the device. We found it is better than cleaving from the backside, because cleaving from the backside would put a compressing force to the device films and damage the device cross-section we worked on. The samples were fresh cleaved and measured by KPFM in glovebox.

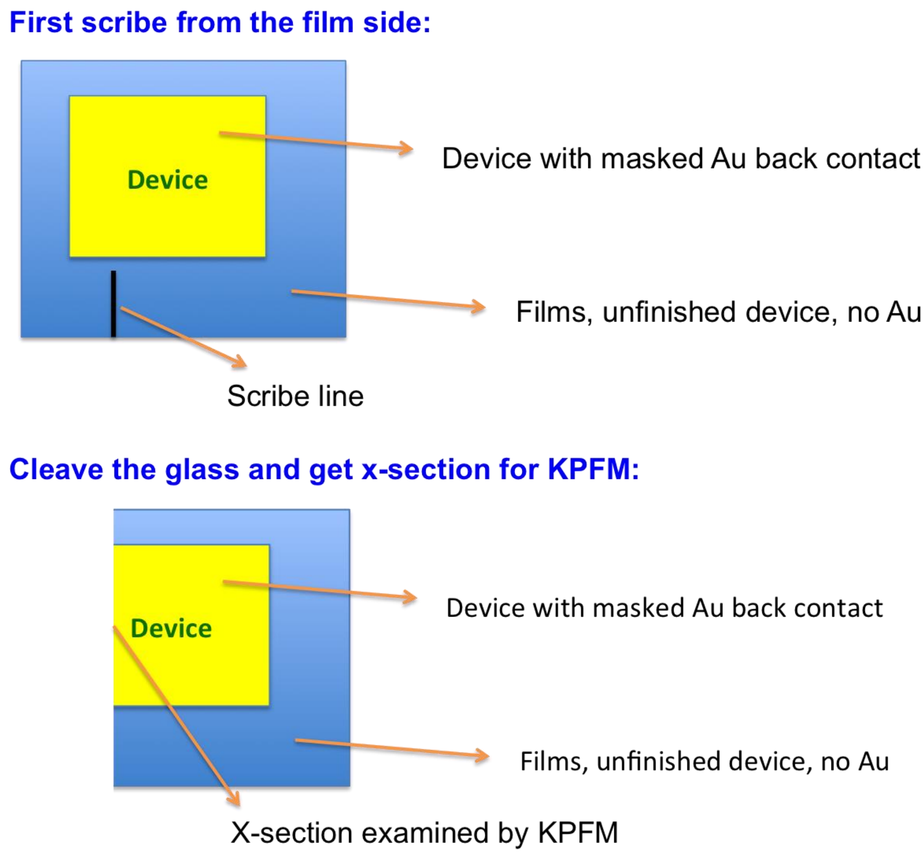

Figure S1. Sketch of how to cleave the sample to expose the cross-section.

J-V and EQE

J-V curves were measured using a Keithley2400 sourcemeter under standard AM1.5 illumination using a solar simulator (PV Measurements Inc.) with an output intensity of 100 mW/cm^2. For light intensity dependence test, the light intensity was later adjusted between 0.794 and 100 mW/cm^2 using neutral density filters. External quantum efficiency (EQE) measurement was carried out with a spectral response system (PV Measurements Inc,) using 100 Hz chopped monochromatic light ranging from 300 nm to 900 nm under relatively near-dark test conditions.

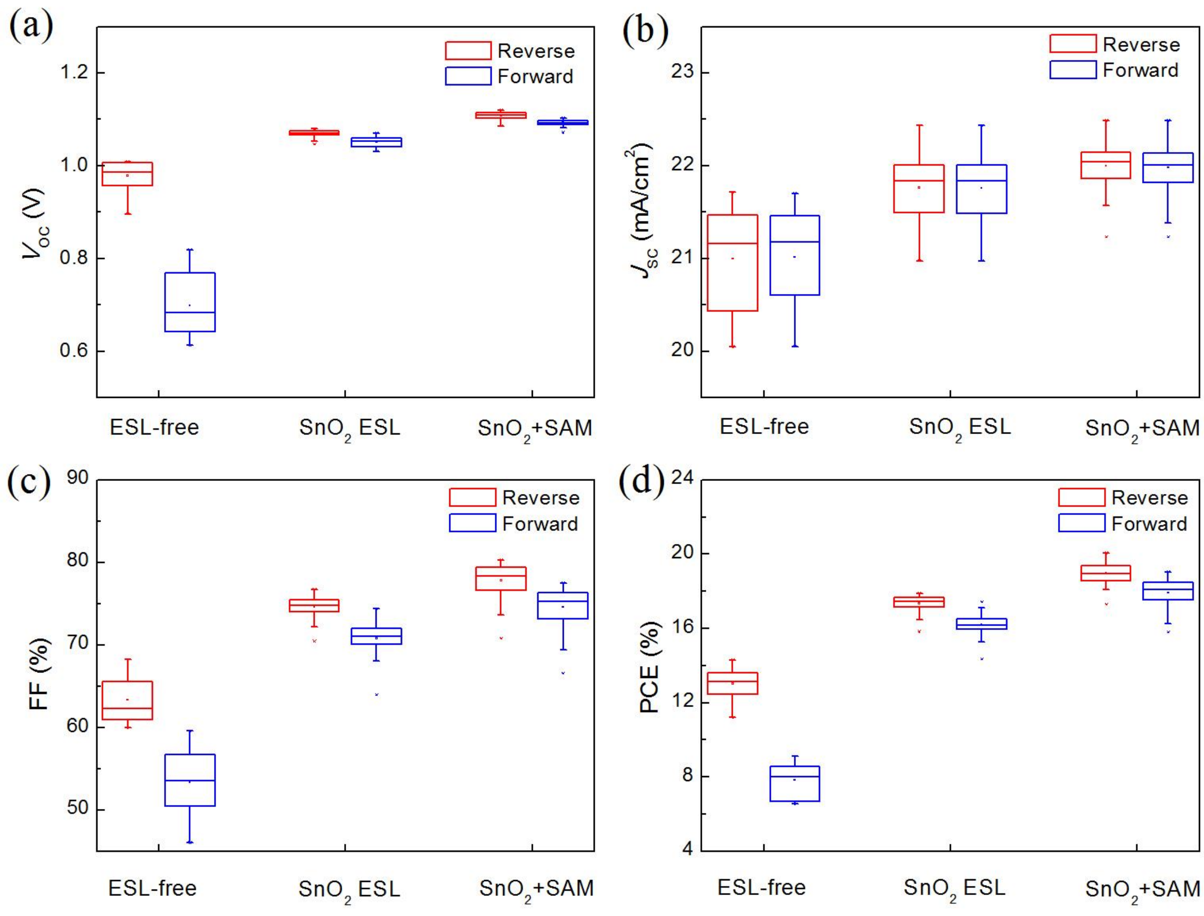

Figure S2. Statistical performance of the three types of ESL cells, a)open-circuit voltage, b) short-circuit current, c)fill factor and d) efficiency.

Table S1. Statistical results of photovoltaic parameters of 94 cells made using SnO_2 ESLs, error values represent the standard deviation.

samples	Scan directions	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
ESL-free	Reverse	0.98±0.03	21.00±0.57	63.35±2.80	13.02±0.80
	Forward	0.70±0.01	21.01±0.53	53.38±4.03	7.84±0.92
SnO_2 ESL	Reverse	1.07±0.01	21.76±0.32	74.59±1.35	17.35±0.43
	Forward	1.05±0.01	21.76±0.33	70.83±1.91	16.20±0.52
SnO_2+ SAM	Reverse	1.11±0.01	22.00±0.26	77.83±2.19	18.97±0.61
	Forward	1.09±0.01	21.98±0.27	74.61±2.48	17.93±0.80

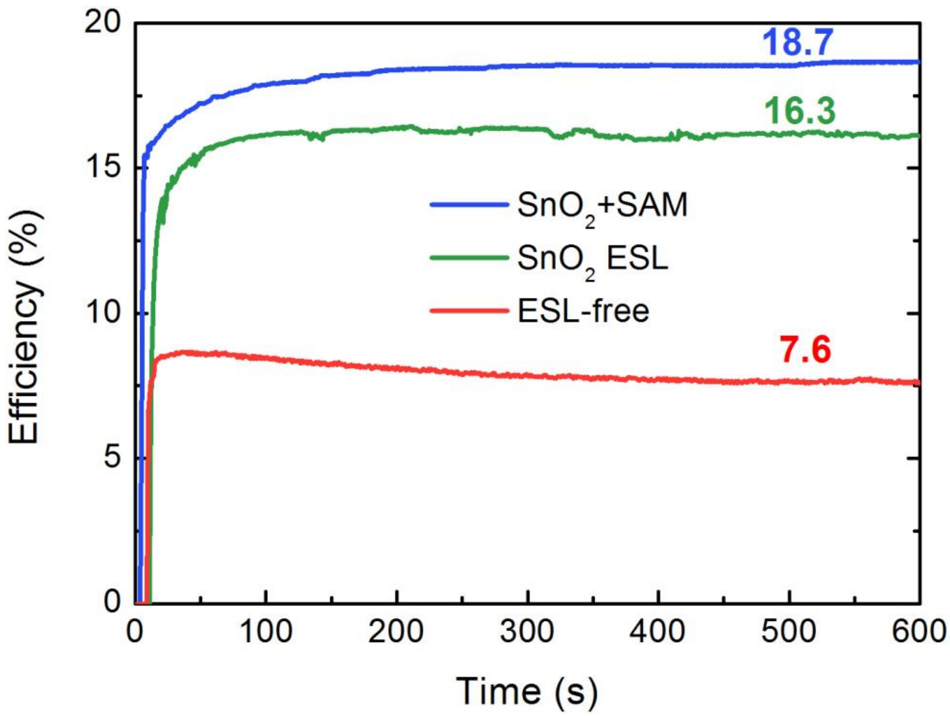

Figure S3. Typical stable output of the three types of ESL cells.

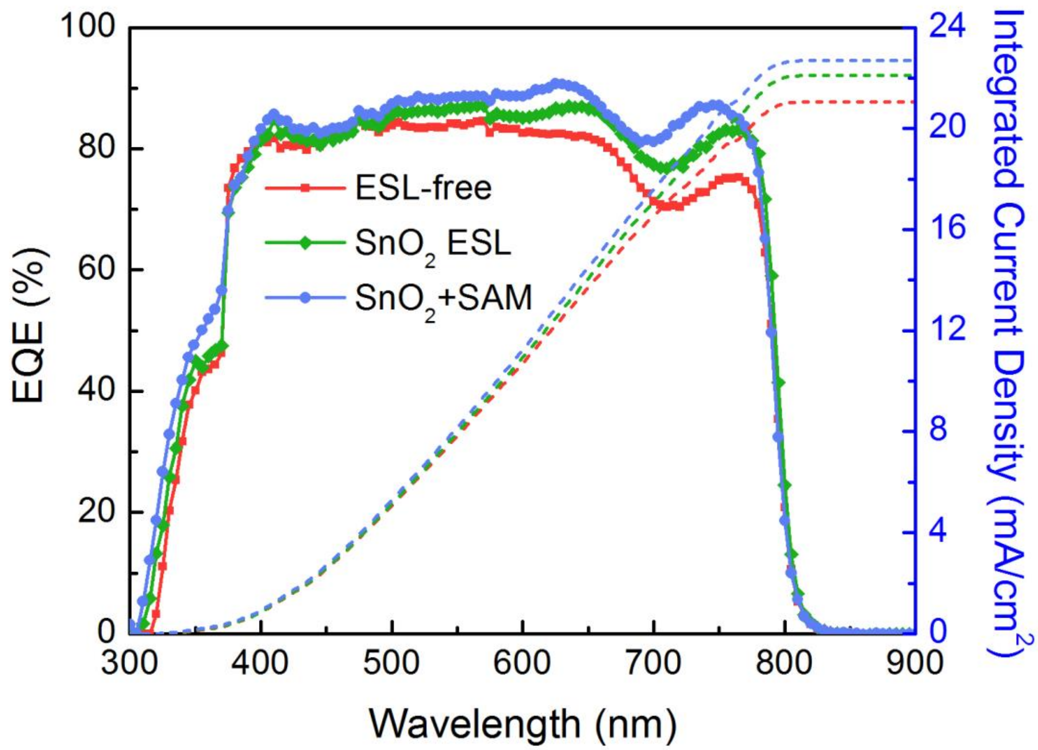

Figure S4. Typical EQE of the three types of ESL cells.

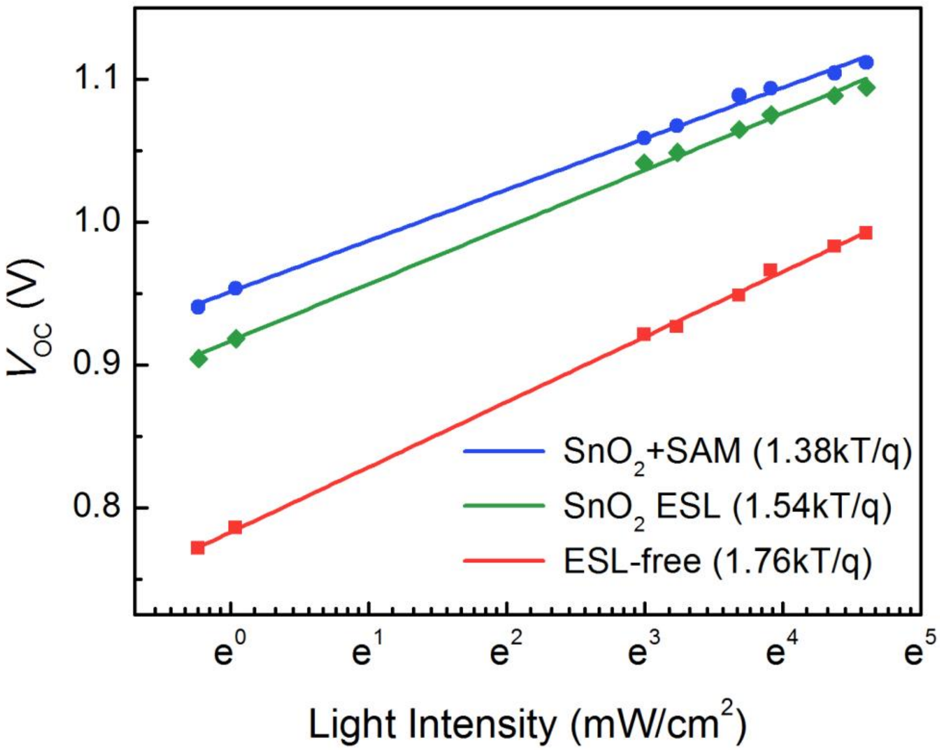

Figure S5. Typical light dependence of Voc of the three types of ESL cells.

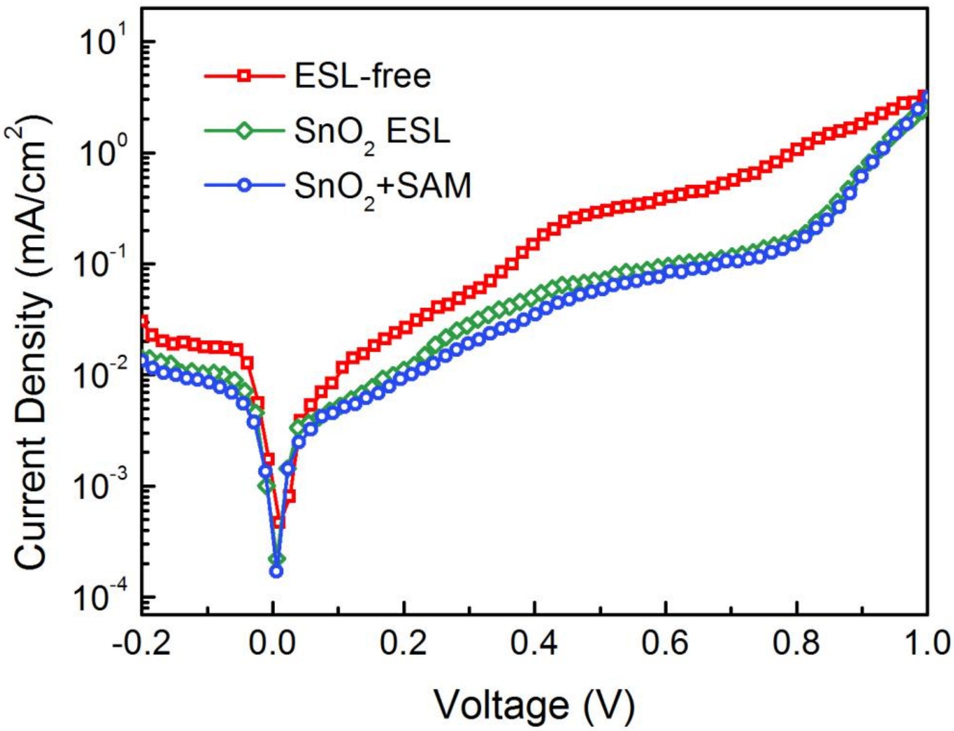

Figure S6. Typical dark I-V curves of the three types of ESL cells.

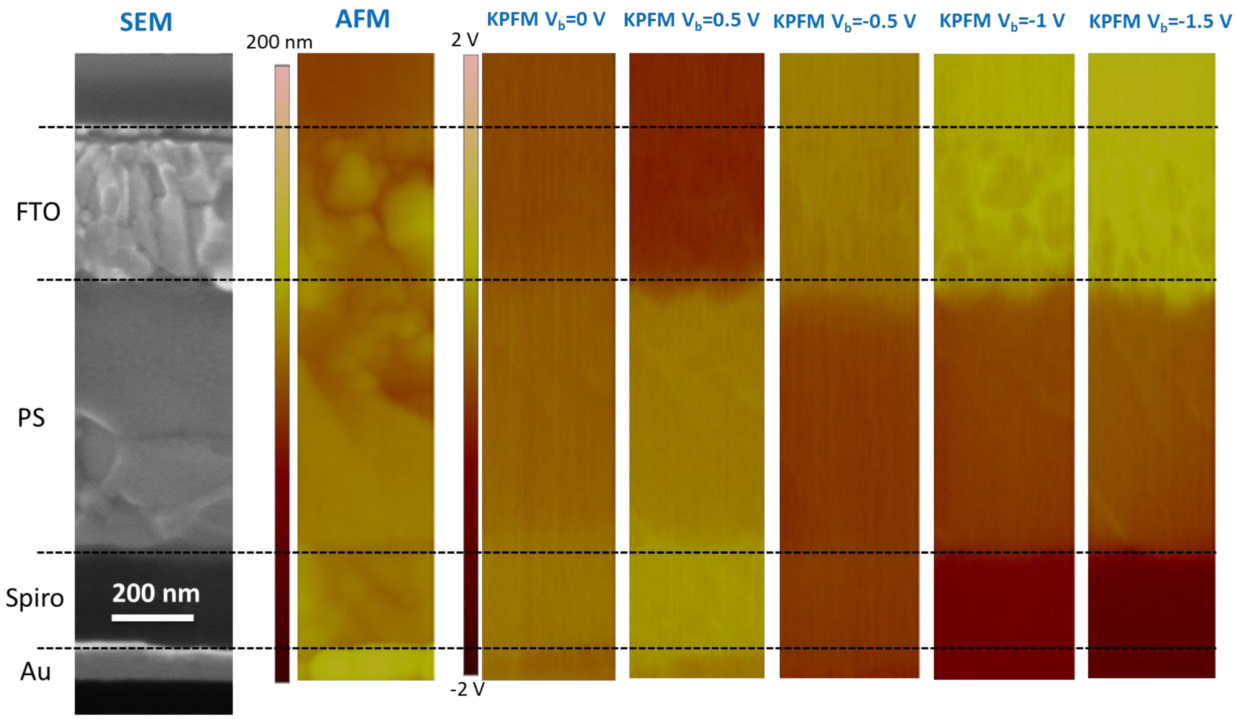

Figure S7. An SEM image showing layer structure of the ESL-free cell, AFM image of the cross-section; and potential imaging across the cell under different bias voltages under V_b=0, +0.5, -0.5, -1, -1.5 V.

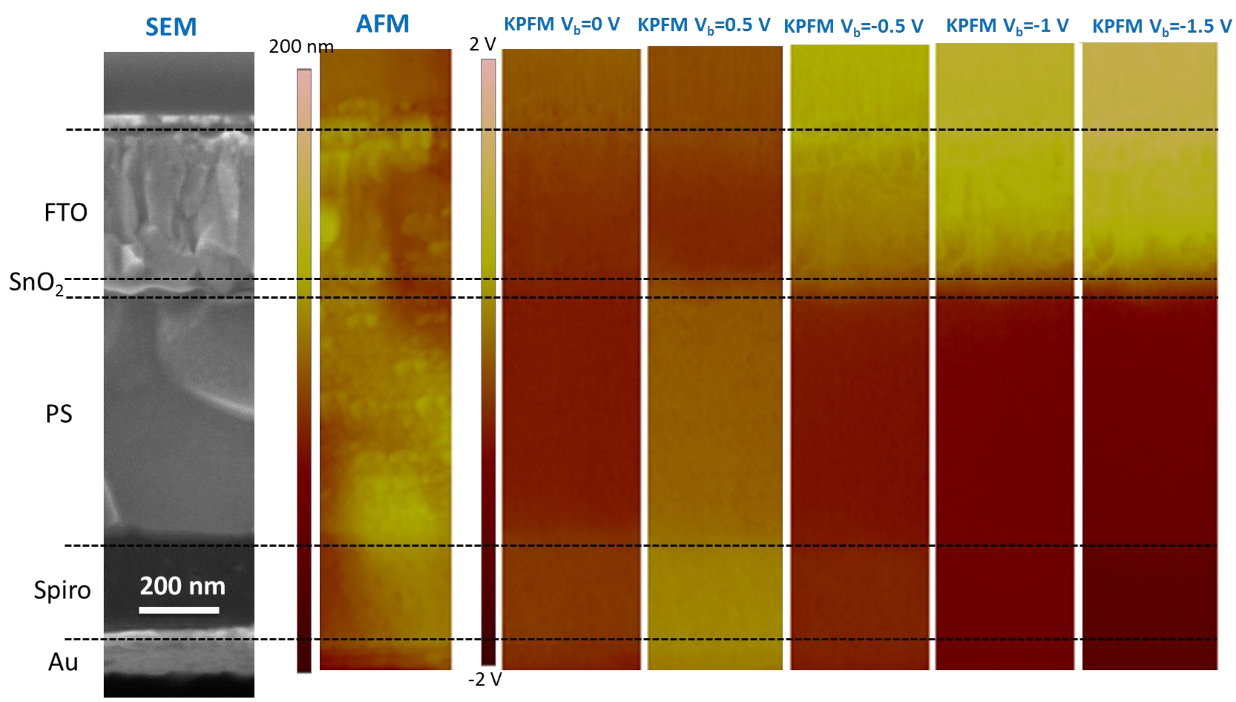

Figure S8. An SEM image showing layer structure of the SnO_2 ESL cell, AFM image of the cross-section; and potential imaging across the cell under different bias voltages under V_b=0, +0.5, -0.5, -1, -1.5 V.

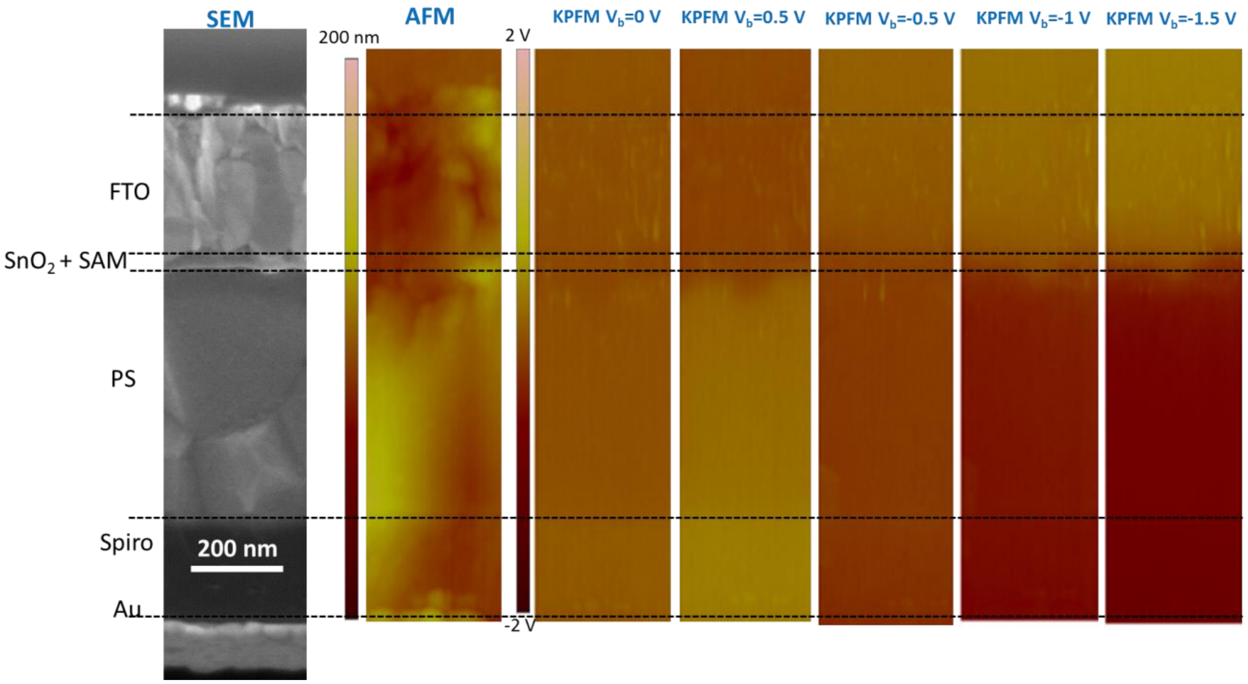

Figure S9. An SEM image showing layer structure of the SnO_2 + SAM cell, AFM image of the cross-section; and potential imaging across the cell under different bias voltages under V_b=0, +0.5, -0.5, -1, -1.5 V.

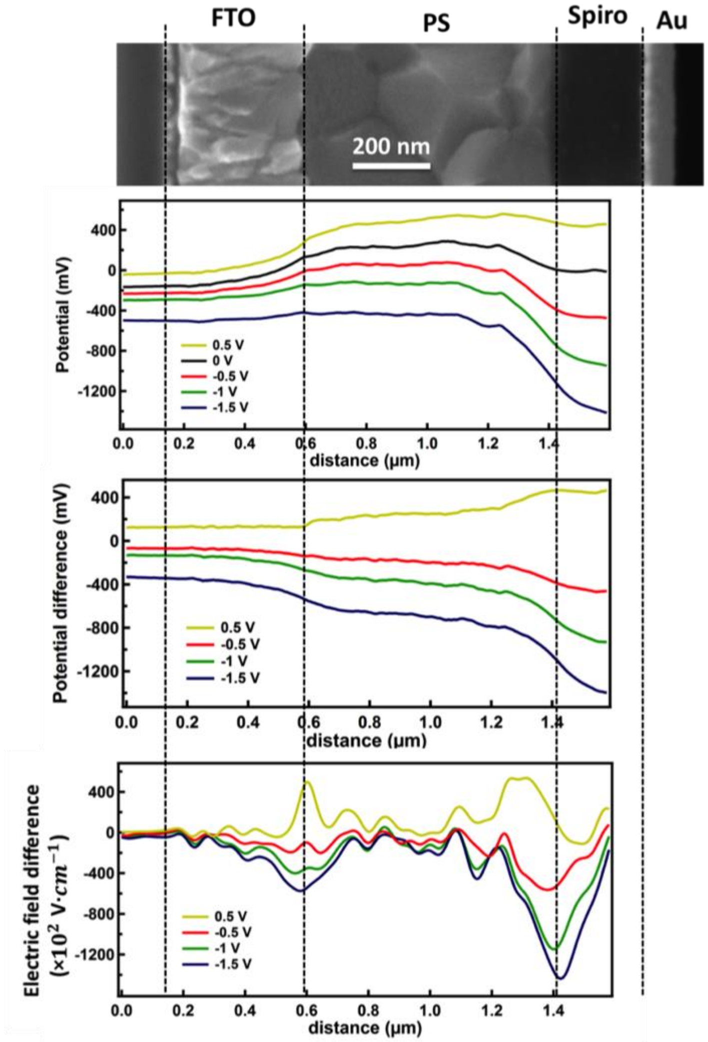

Figure S10. Potential profiling of ESL-free cell similar to Figure 3.

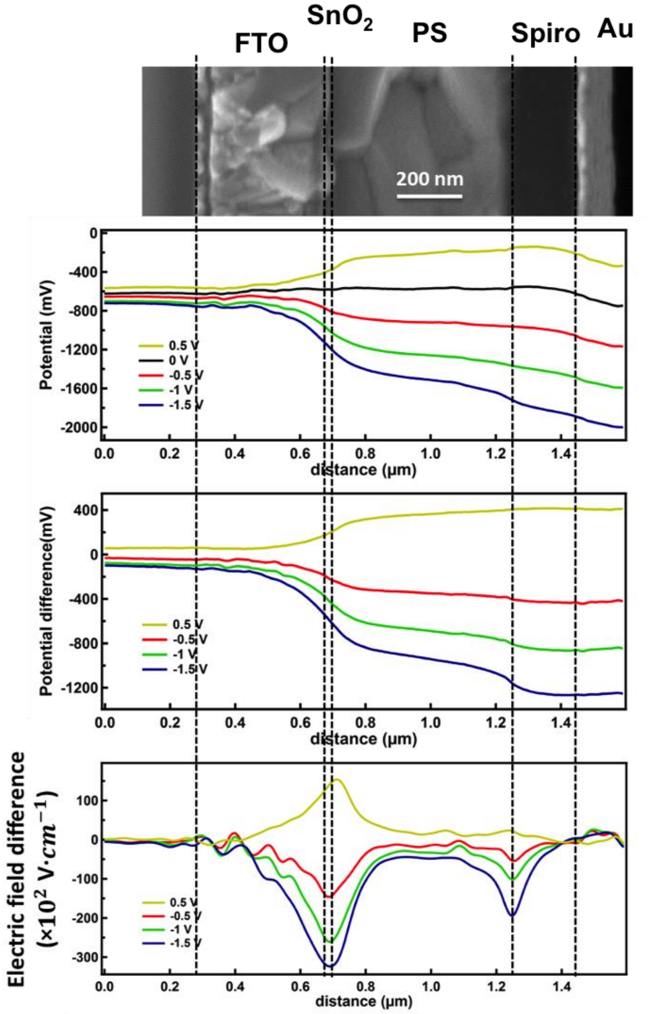

Figure S11. Potential profiling of SnO_2 ESL cell similar to Figure 4.

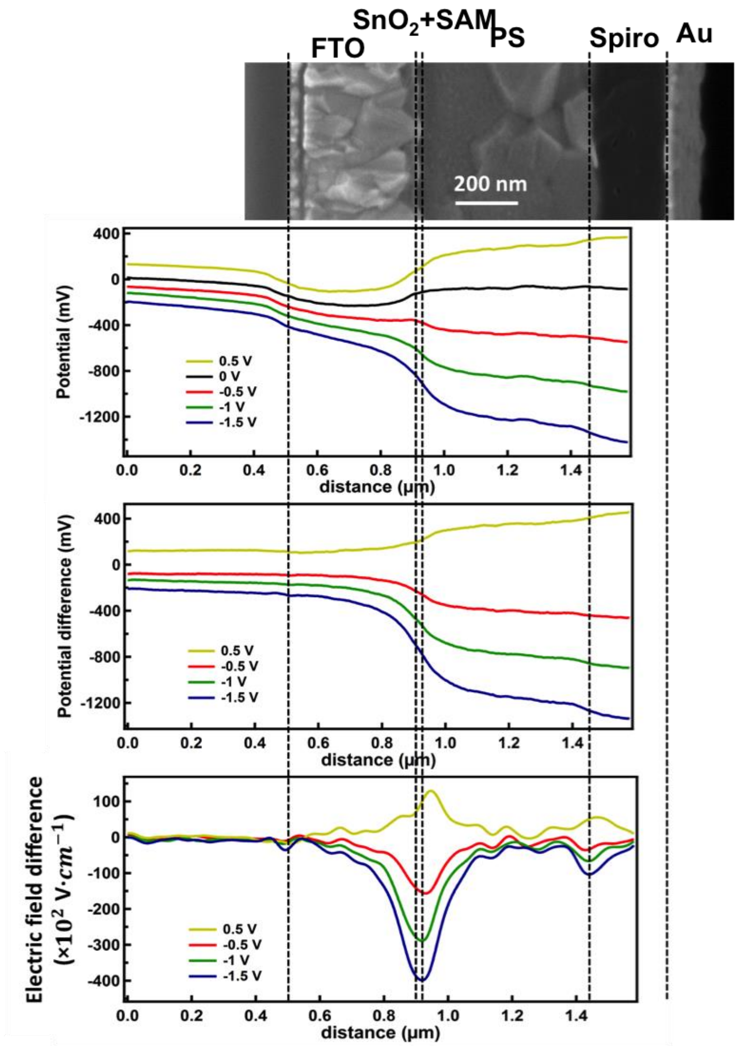

Figure S12. Potential profiling of SnO_2 + SAM cell similar to Figure 5.