Supplementary Information

Flexible, low-temperature, solution processed ZnO-based perovskite solid state solar cells.

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Experimental

Device fabrication

Indium tin oxide coated PET (60 Ω/sq, Sigma Aldrich) was etched with sand paper and cleaned in decon soap solution and deionized water subsequently for 20 min each. The ZnO compact layer (200 nm) was deposited by cathodic electrodepositon at -0.8 V vs Ag/AgCl in 0.05 M $Zn(NO_3)_2.6H_2O$ solution held at 70 °C for 10 min.[1] The ZnO nanorods were grown on the seeded substrates by CBD technique at 90 °C for 90 min following procedures reported elsewhere.[2] In short, the deposition solution consists of 0.03 M $Zn(NO_3)_2{\cdot}6H_2O$, 0.025 M hexamethylenetetramine (HMTA), and 0.005 M polyethyleneimine (PEI, Mw = 800 $gmol^{-1}$).After the growth, samples were thoroughly rinsed with DI water. The final nanorod length is between 400-500 nm.

The organic-inorganic perovskite $(CH_3NH_3)PbI_3$ was deposited by sequential method as reported in the literature.[3] Lead iodide (1M) was dissolved in N,N-dimethyl formamide overnight under stirring conditions at 70 °C. Infiltration of PbI_2 on the ZnO films was done using spin coating at 6000r.p.m for 5 s and then the substrates were dried for 30 min at 70 °C. The films were dipped in a solution of CH_3NH_3I in 2-propanol (10mgml^{-1}) for approx. 20 min, and then rinsed with 2-propanol and dried at 70 °C for 30 min to form the final $CH_3NH_3PbI_3$ perovskite layer. The hole transporting material was then spin coated onto the perovskite loaded films at 4000 rpm for 30s followed by thermal deposition of gold (80-90 nm thick) to form the back contact. The hole transporting material deposition solution comprised of 2,2',7,7'-tetrakis-(N,N-di-p-methoxyphenylamine) 9, 9'-spirobifluorene (spiro-MeOTAD) in chlorobenzene, 48 μL of 4-tert-butylpyridine (TBP), 29 μL of stock solution of (LiTFSI) in acetonitrile (ACN) [3]and 14.4 mg of FK102 dopant[4] in 48 μL of ACN.120 mg/ml concentration was used for planar ZnO devices and 90 mg/ml concentration for ZnO nanorod based devices. The active areas of the devices fabricated in this work were 0.2 cm^2. During measurements, samples were masked using a black tape with 0.25 cm^{2}aperture, to define the illuminated area.

Characterization

Current density-voltage (j-V) plots were measured using solar simulator (San-EI Electric, XEC-301S, AM 1.5, 100 mW/cm^2). The current-voltage data under these conditions was obtained using Keithley model 2612A source meter. IPCE measurements were performed using PV300 (Bentham), with dual Xenon/quartz halogen light source, measured in DC mode with no bias light. Incident light intensity was calibrated using a photodiode detector (silicon calibrated detector, Newport). All the measurements were performed in air. UV-Vis absorption spectra were collected with a Shimadzu UV3600 spectrophotometer coupled with an integrating sphere. Structural and phase characterization of the as-prepared film was done by X-ray diffraction (XRD). The XRD patterns were recorded using Bruker AXS (D8 ADVANCE) X-ray diffractometer with Cu Kα radiation (λ = 1.54 Å) from 20^0 to 80^0. The surface morphology was characterized by FESEM (JEOL, JSM-7600F) with an accelerating voltage of 5 KeV. Impedance spectroscopy (IS) was measured under a white LED illumination (current matched to the AM 1.5 standard condition) with an Autolab 302 at different DC bias potentials between Jsc and Voc. The applied voltage perturbation had AC amplitude of 20 mV (rms) with a frequency from 1 MHz to 1 Hz. The spectra were fitted using Z-View software.

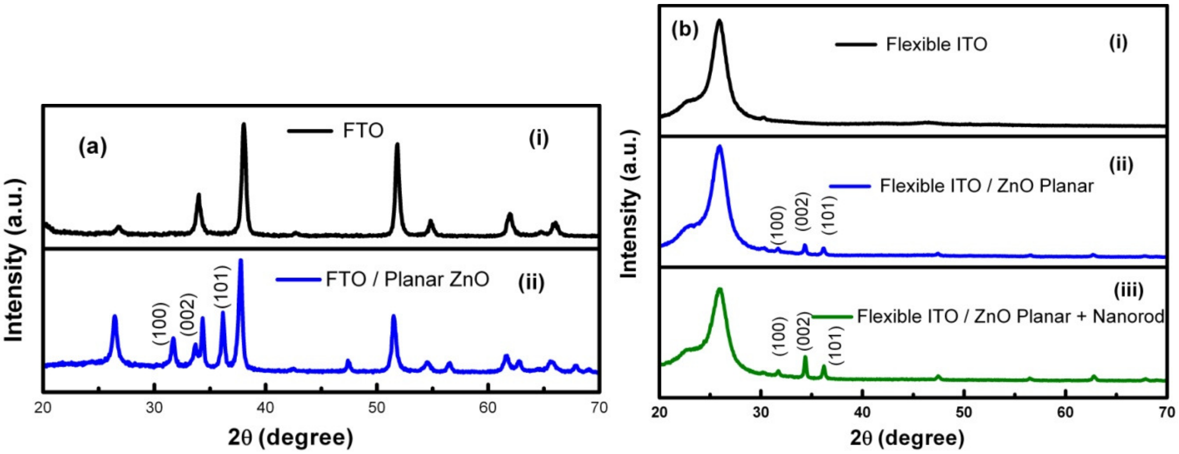

Figure S1. XRD pattern of **(a)** FTO and planar ZnO on FTO, **(b)**PET/ITO, ZnO planar and ZnO planar with the ZnO nanorods.

XRD Spectra for both the ZnO electrodeposited on FTO and PET/ITO show no additional peaks and agree with ICDD PDFNo. 99-101-1339, confirming the quality and purity of the ZnO electrodeposited films. It is also observed that ZnO nanorods grown by CBD technique on the compact layer are oriented in the (002) direction.

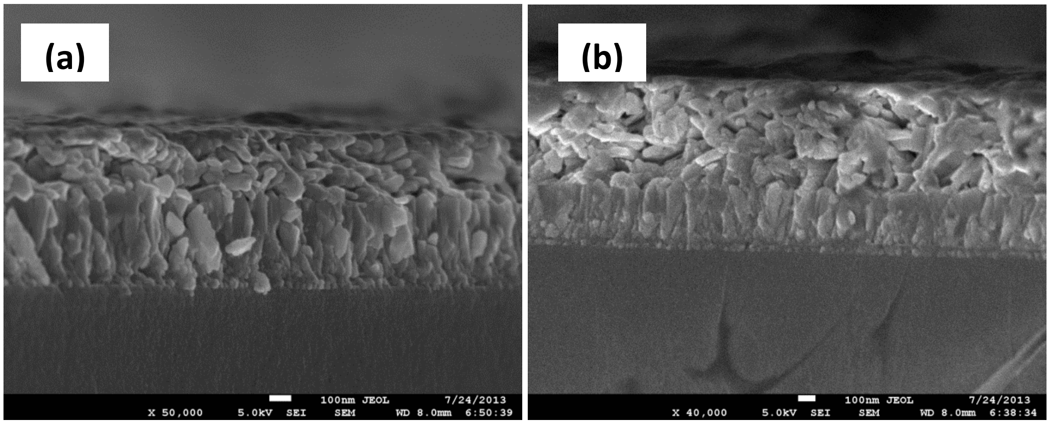

Figure S2. FESEM images of **(a)** cross-section of planar ZnO/FTO sample after PbI_2 deposition and **(b)** cross-section of ZnO nanorod FTO sample after PbI_2 deposition.

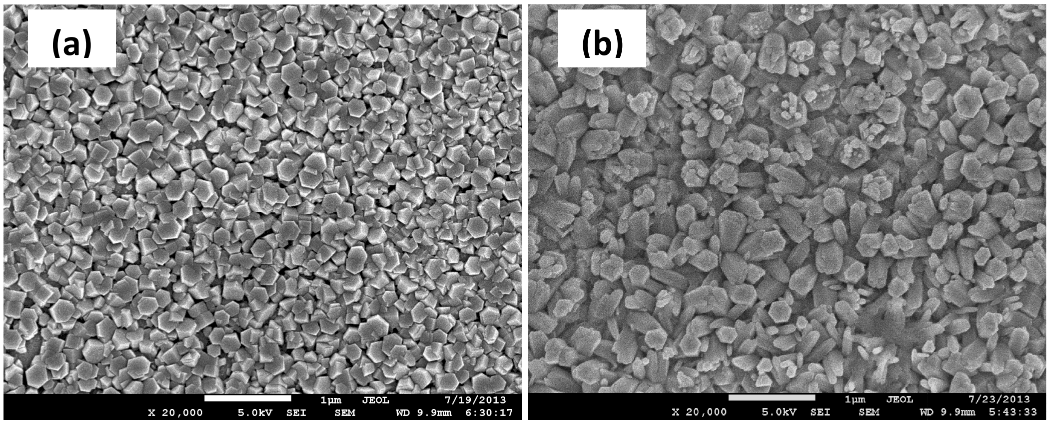

Figure S3.FESEM images of **(a)** top view of ZnO compact layer electrodeposited on PET/ITO, **(b)** top view of ZnO nanorods grown on ZnO compact layer on PET/ITO.

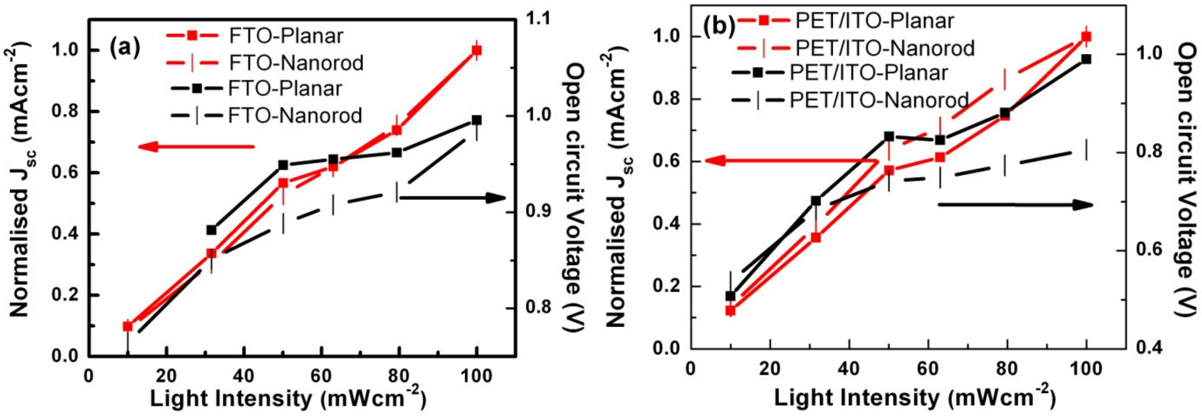

Figure S4.(a) Normalised short circuit photocurrent and open circuit voltage plotted versus different light intensities for devices on FTO substrate; **(b)** Normalised short circuit photocurrent and open circuit voltage plotted versus different light intensities for devices on PET/ITO substrates.

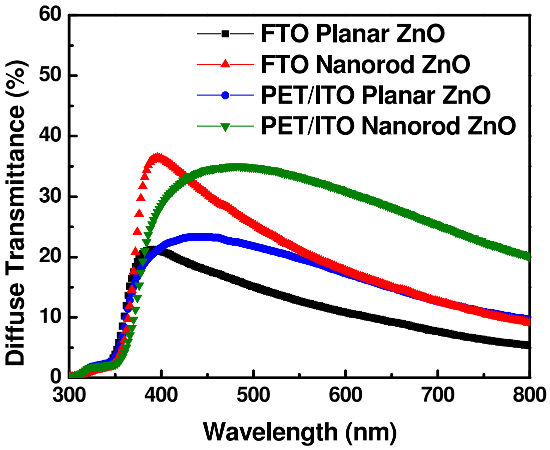

Figure S5. Diffuse transmittance of ZnO on various substrates employed in this study. Diffuse transmittance measurements were done by measuring the transmittance inside integrating sphere without the back reflectance to eliminate the direct transmittance.

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4. J. Burschka, A. Dualeh, F. Kessler, E. Baranoff, N. L. Cevey-Ha, C. Yi, M. K. Nazeeruddin and M. Grätzel, *Journal of the American Chemical Society*, 2011, **133**, 18042-18045.