Supplementary Information

Solubilization of carbon nanotubes with ethylene-vinyl acetate for solution-processed conductive films and charge extraction layers in perovskite solar cells

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KEYWORDS: Carbon nanotubes, conductive films, CNT polymer functionalization, insulating polymer, perovskite solar cells.

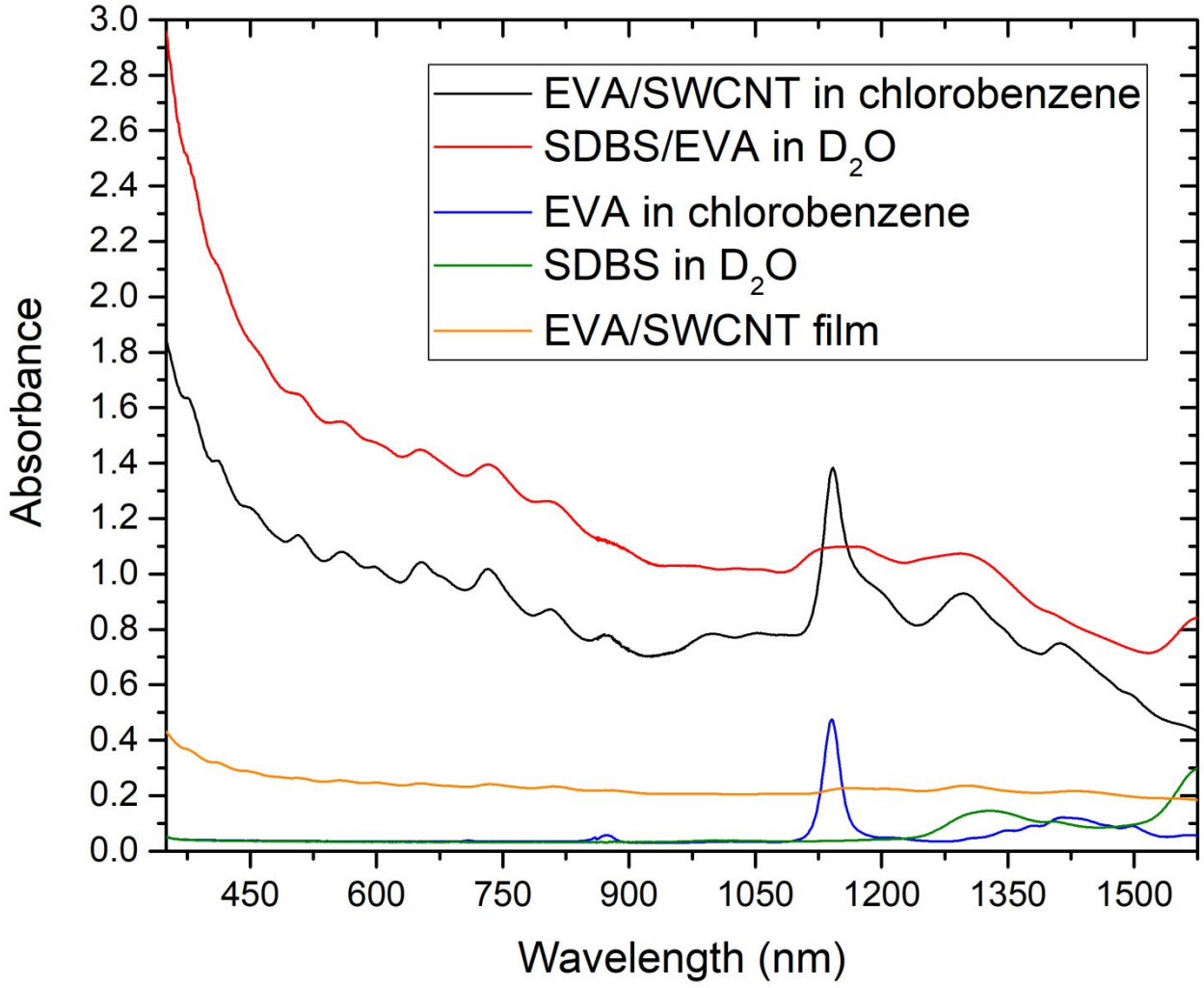

Figure S1 Absorption spectra of EVA/SWCNT in chlorobenzene (black solid line), SDBS/SWCNT in heavy water (D_2O, red solid line), EVA in chlorobenze (blue solid line) and SDBS in D_2O (green solid line).

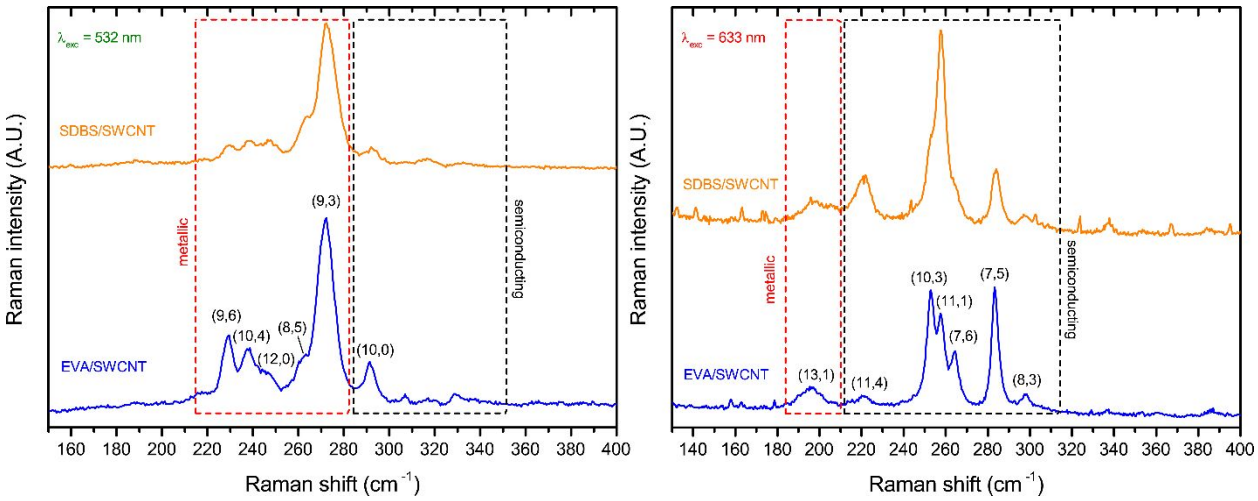

Figure S2 Raman spectra of EVA/SWCNT and SDBS/SWCNT obtained using an excitation wavelength of 532 nm (left) and 633 nm (right). Both spectra show large peaks corresponding to metallic SWCNT, marked by the red dotted rectangle in both graphs.

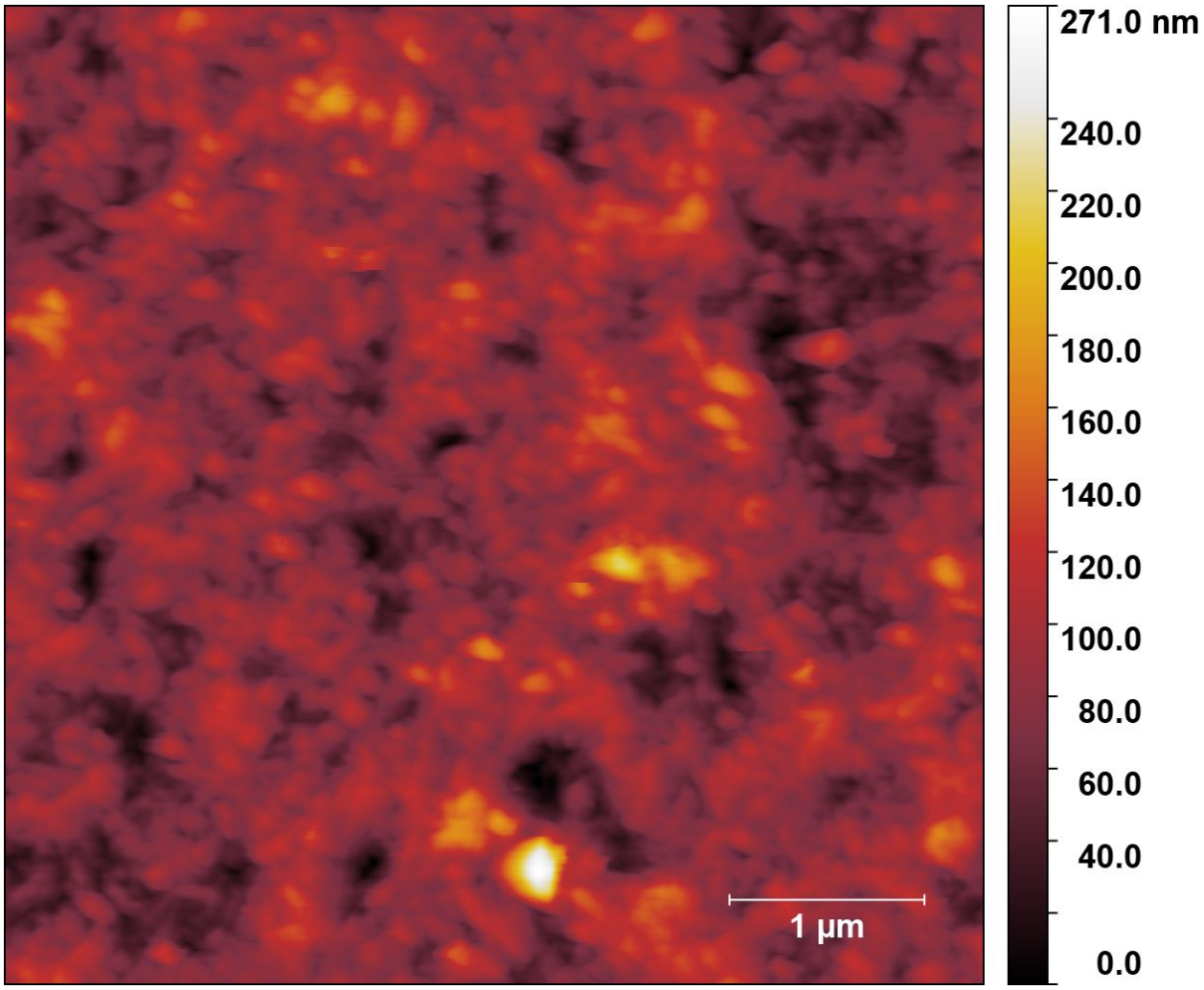

Figure S3 AFM image of a spray-coated MWCNT/EVA film on glass. The film has an approximate thickness of 80 nm, with a RMS roughness of 26 nm. Despite few regions with higher peaks, the map shows a dense coverage of the substrate.

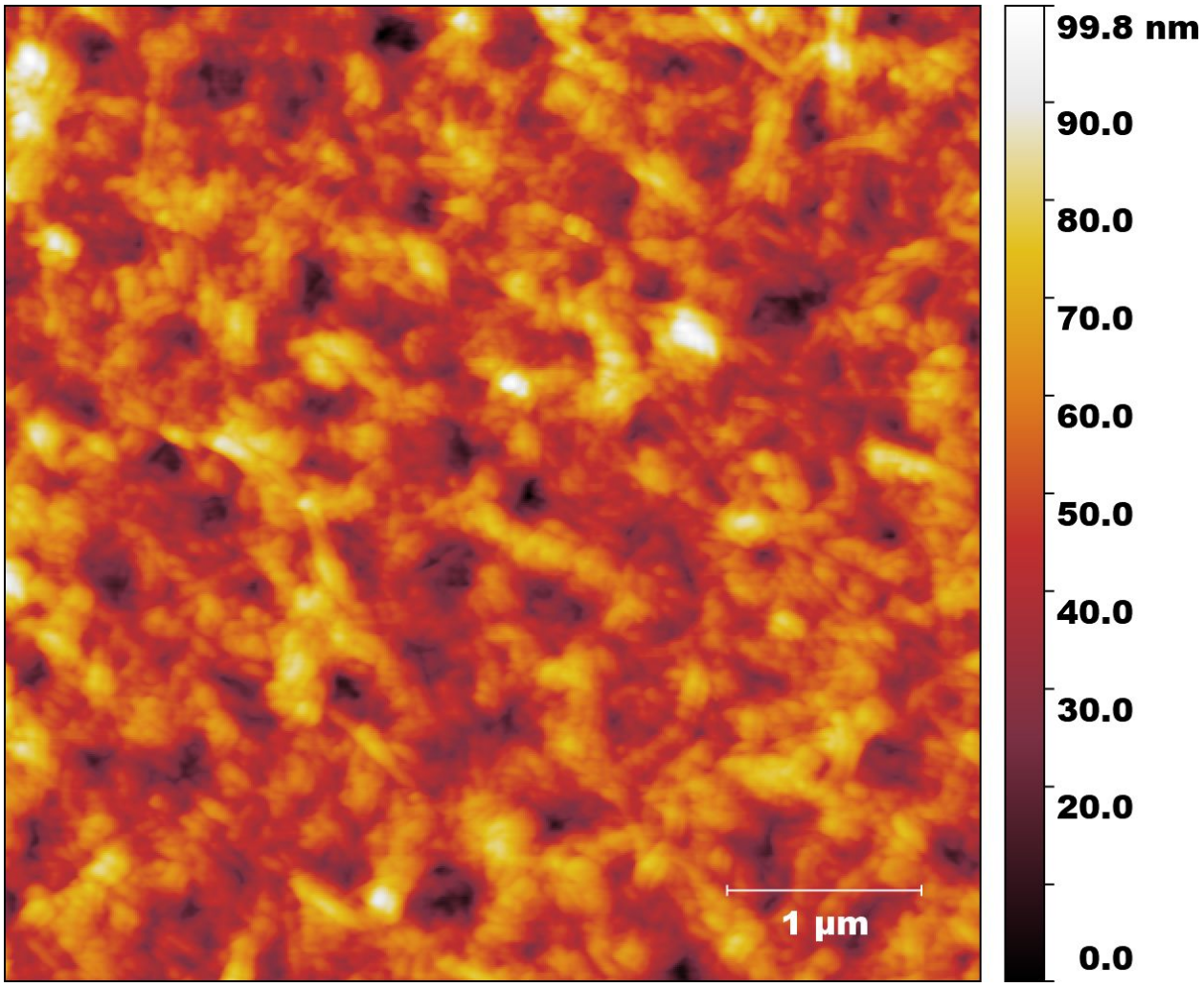

Figure S4 AFM image of a spray-coated SWCNT/EVA film on glass. The film has an approximate thickness of 80 nm, with a RMS roughness of 13 nm. The map shows a smoother film compared to the MWCNT film in Figure S1, likely due to the shorter length of individual SWCNTs compared to MWCNTs.

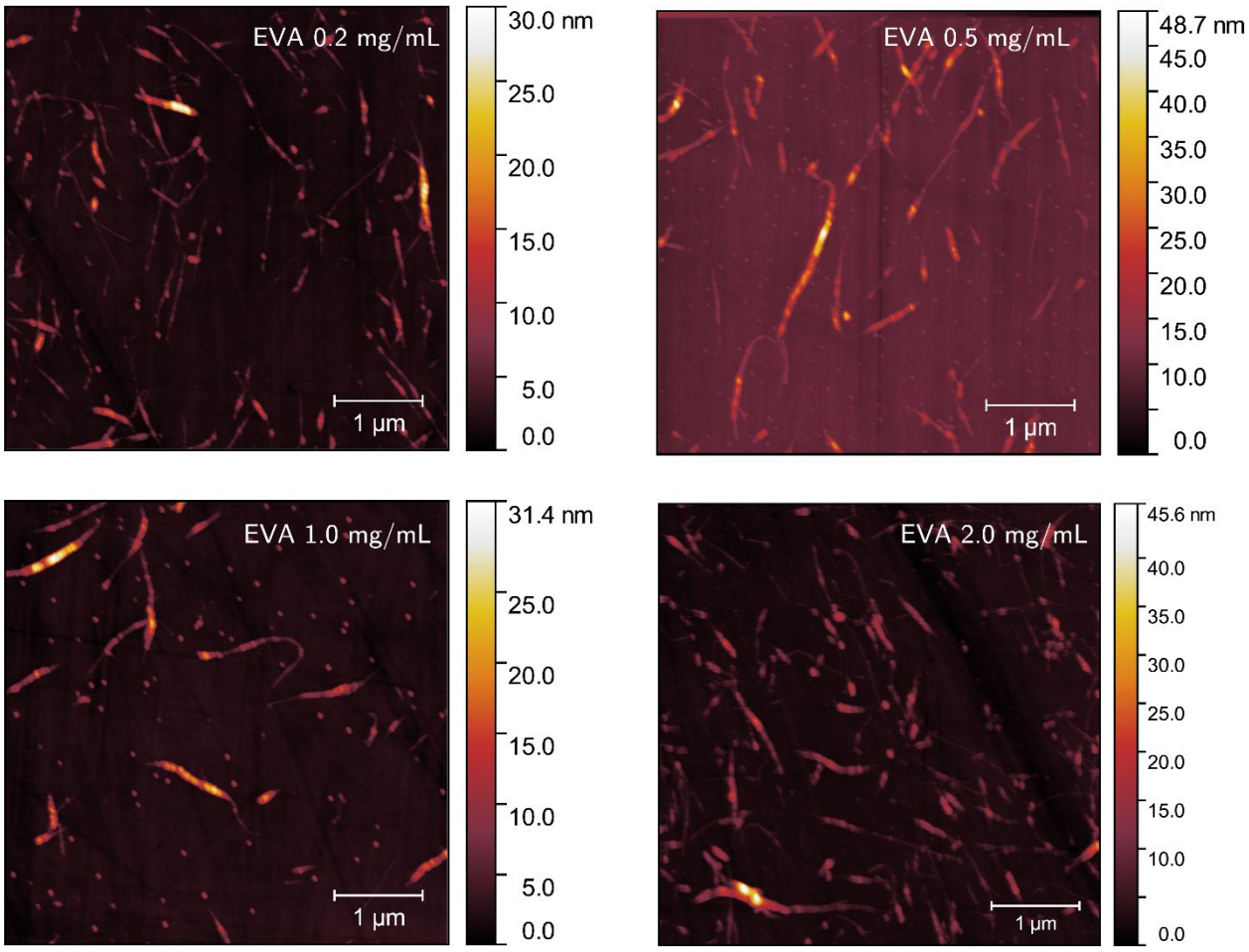

Figure S5 AFM images of diluted EVA/SWCNT nanohybrids on glass obtained from different EVA polymer concentrations (indicated in the top-right corner of each map). In all the four images it is possible to observe individual SWCNTs.

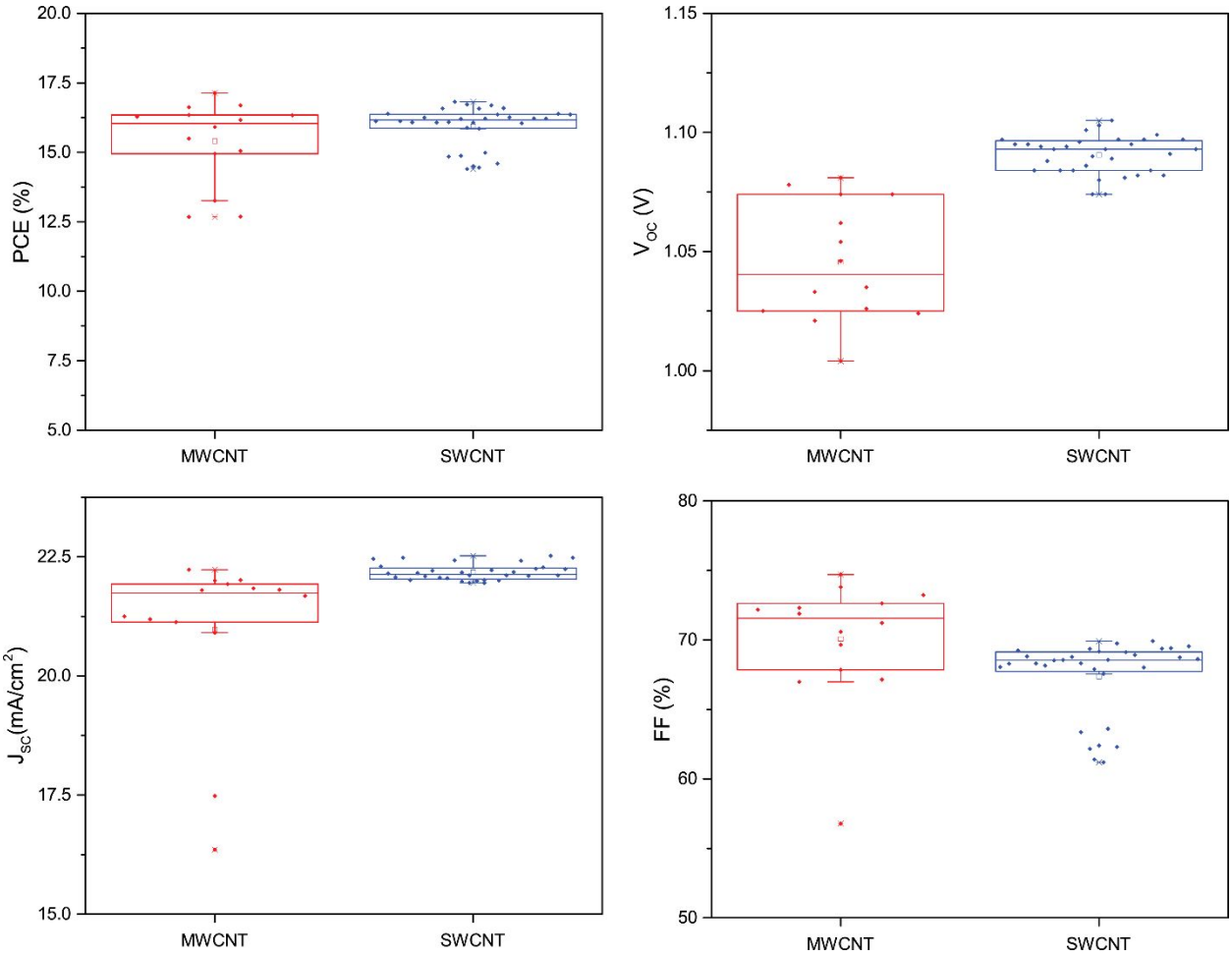

Figure S6 Performance parameters of EVA/CNT films as hole extraction layer in perovskite solar cells. MWCNT devices have a $FA_{0.83}Cs_{0.17}Pb(I_{0.9}Br_{0.1})_3$ perovskite absorber while SWCNT devices have a $FA_{0.83}MA_{0.17}Pb(I_{0.83}Br_{0.17})_3$ perovskite. The box plots compare the power conversion efficiency (PCE), open circuit voltage (V_{OC}), short circuit current (J_{SC}) and fill factor (FF) of devices when EVA/SWCNT and EVA/MWCNT are used as hole extraction layer.

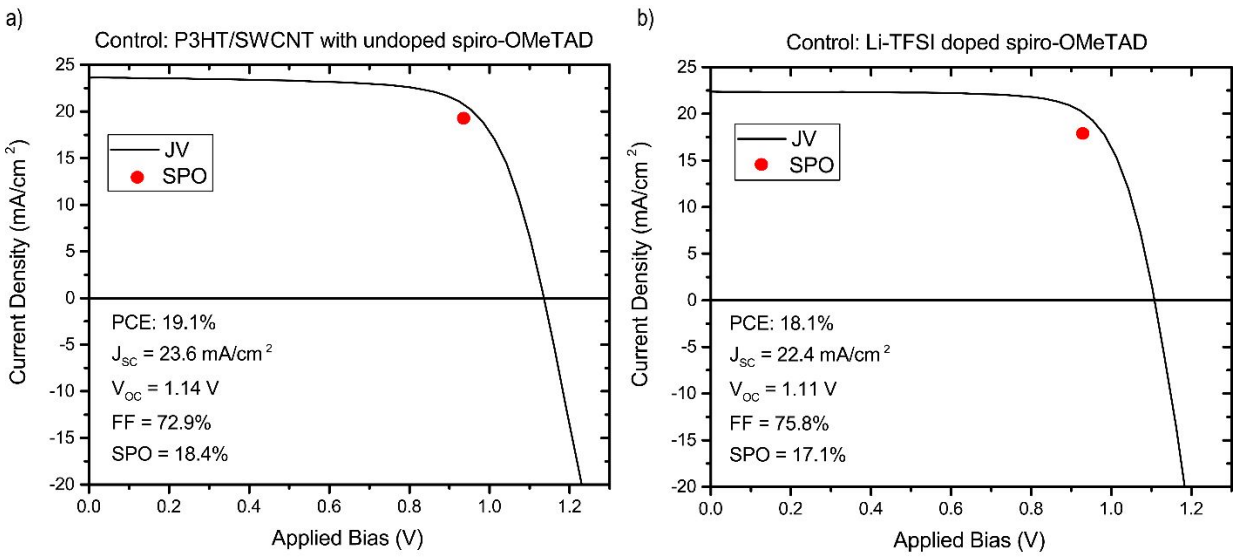

Figure S7 JV curves of control devices. a) $FA_{0.83}MA_{0.17}Pb(I_{0.83}Br_{0.17})_3$ perovskite solar cell having a layer of P3HT/SWCNTs infiltrated with undoped spiro-OMeTAD as a hole extraction layer. b) $FA_{0.83}Cs_{0.17}Pb(I_{0.9}Br_{0.1})_3$ perovskite solar cell having a Li-TFSI-doped spiro-OMeTAD as a hole extraction layer.

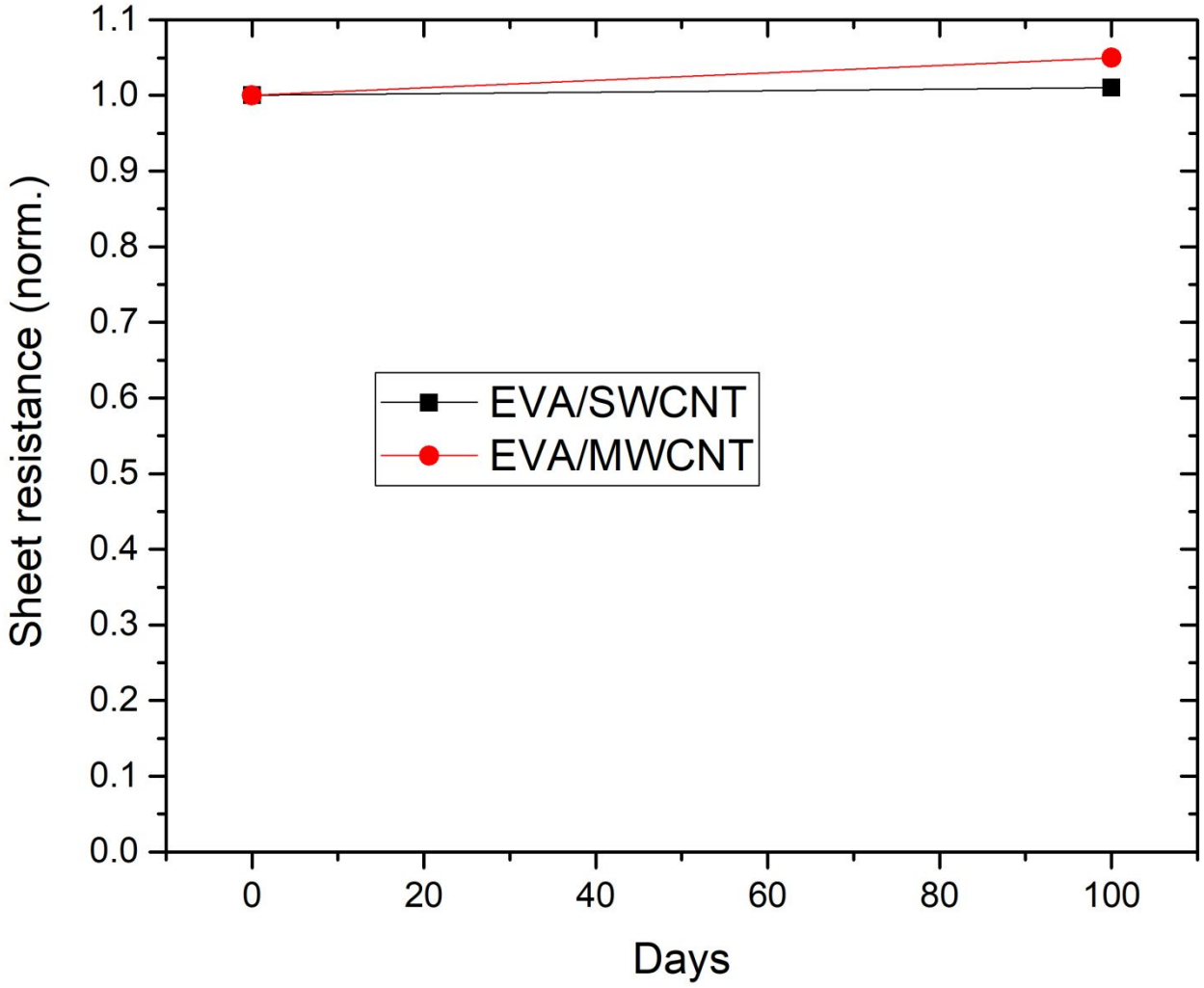

Figure S8 Sheet resistance measurements of EVA/SWCNT and EVA/MWCNT films immediately after fabrication (t=0 days) and after 100 days stored in ambient conditions (shelf life), expressed as a ratio of the initial value.