

Highly Efficient Flexible Perovskite Solar Cells Using Solution-Derived NiO_x Hole Contacts

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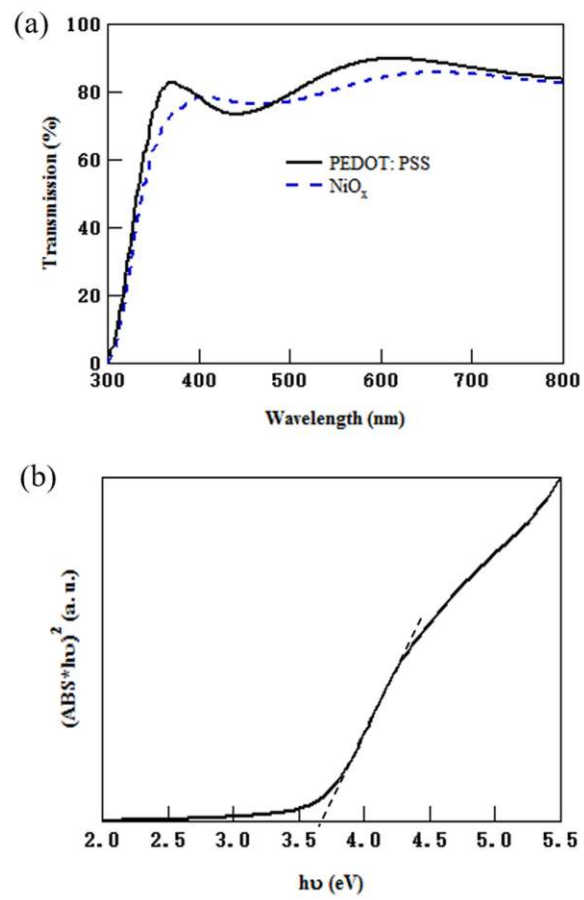


Figure S1. (a) Transmission spectra of the PEDOT: PSS and the NiO_x film on ITO substrate. (b) $(ABS \cdot hv)^2$ as a function of photon energy of the NiO_x film on quartz substrate.

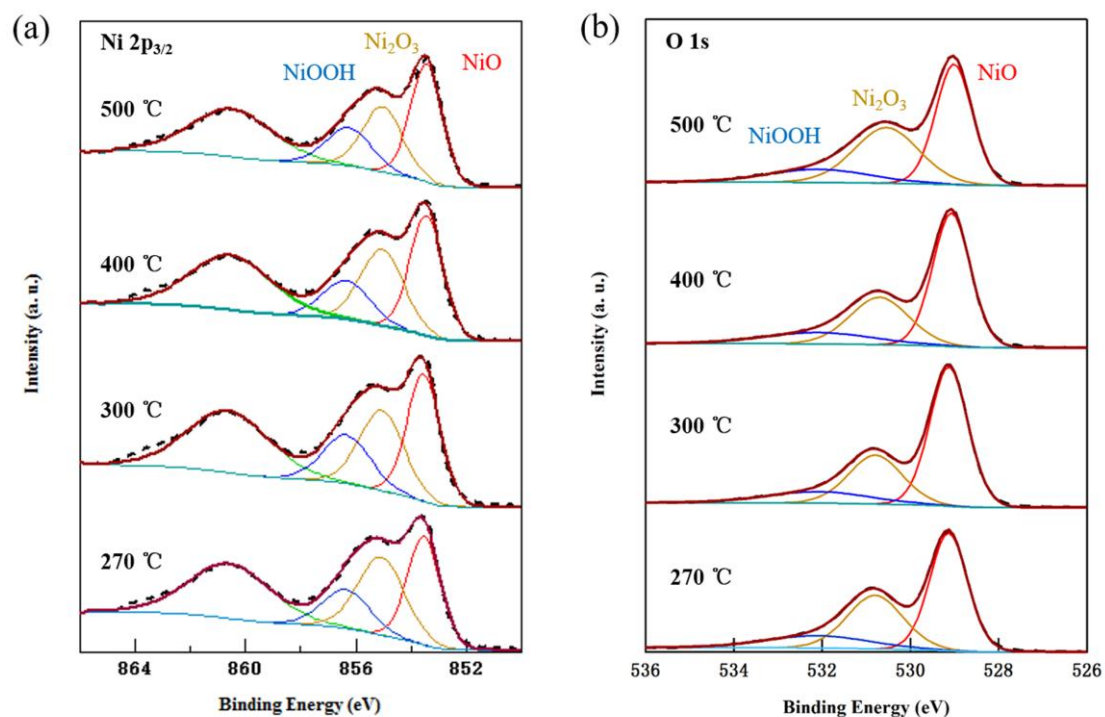


Figure S2. XPS spectra of NiO_x films deposited from NiO_x nanoparticles that were annealed at different temperatures. (a) Ni 2p core level; (b) O 1s core level.

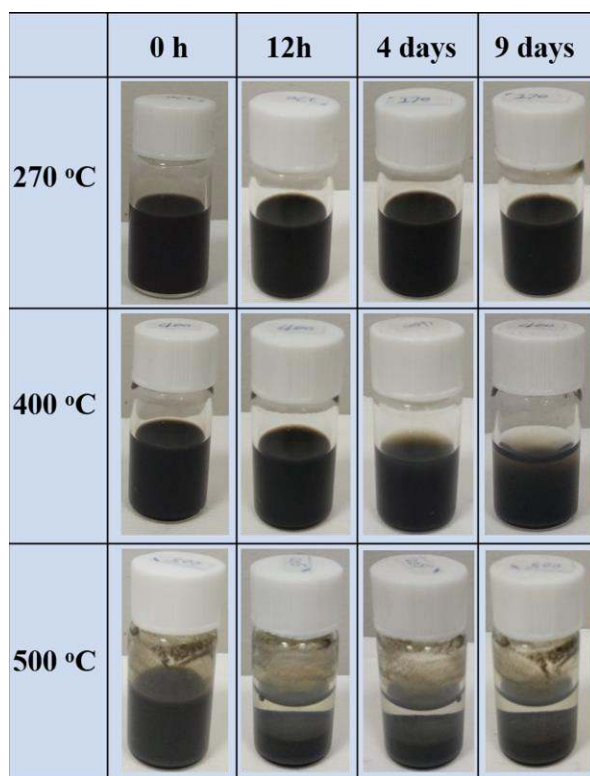


Figure S3. Digital photographs of NiO_x nanoparticle solutions stored for different durations after preparation.

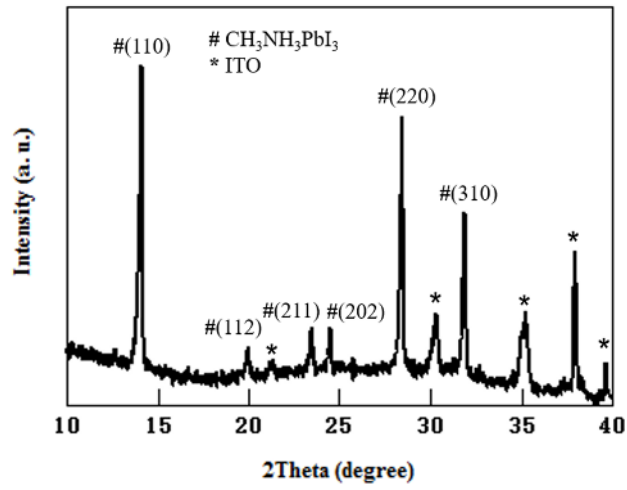


Figure S4: XRD patterns of perovskite film deposited on NiO_x films coated ITO substrate.

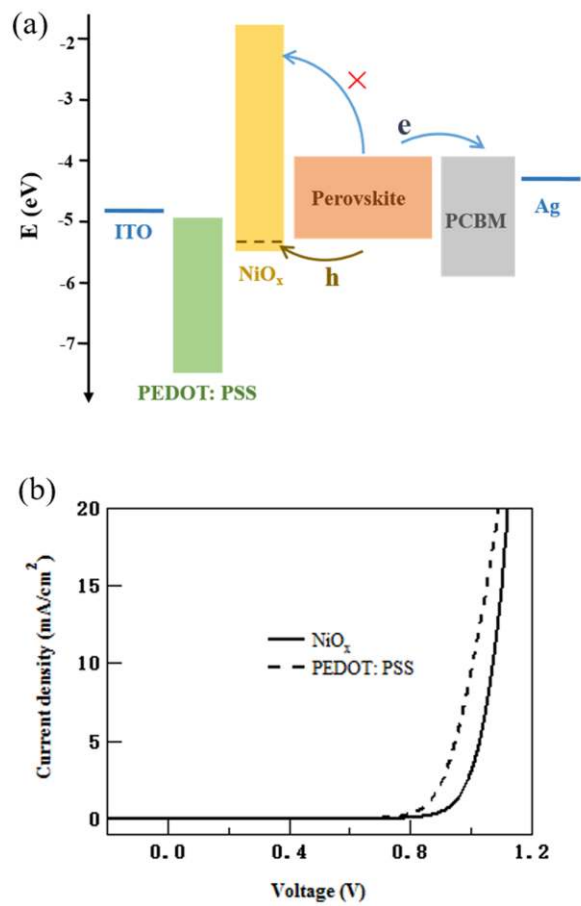


Figure S5: (a) Schematic band diagram of the NiO_x -based perovskite solar cell, in which the band position of PEDOT: PSS is also presented for comparison. The band edge positions for NiO_x were taken from Ref. 34, and the band edge positions of ITO, PEDOT: PSS, perovskite and PCBM were taken from Ref. 19. (b) Dark J-V curves for the fabricated devices based on PEDOT: PSS and NiO_x films, respectively.

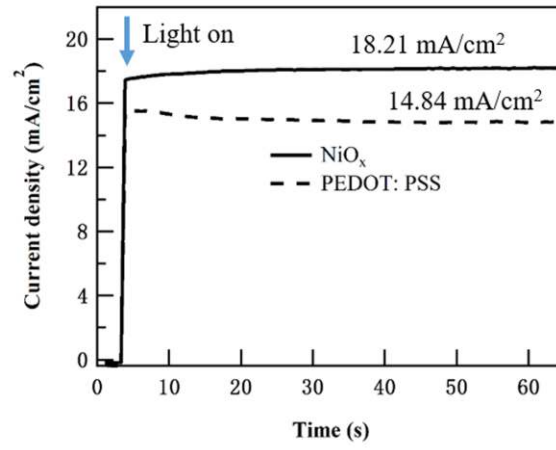


Figure S6: Steady state PCE measurement. The bias voltage for PEDOT: PSS and NiO_x-based devices are 0.75V and 0.89 V, respectively.

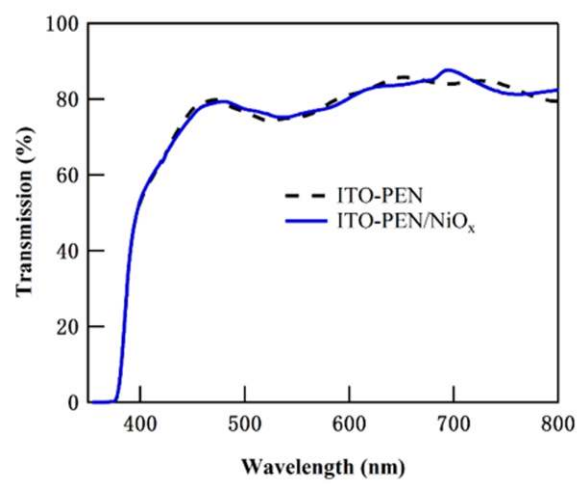


Figure S7. Transmission spectra of PEN substrates with and without NiO_x.

Table S1 Summary on the performances of the reported NiO_x-based organic-inorganic hybrid perovskite solar cells, in which parameters of our devices are also included for comparison. The word “non” means the parameter was not presented in the paper.

Device configuration	V _{oc} (V)	J _{sc} (mA/cm ²)	FF (%)	PCE (%)	Steady state PCE (%)	Area (cm ²)	Method/temperature	Reference
ITO/Cu:NiO/CH ₃ NH ₃ PbI ₃ /Bis-C ₆₀ /C ₆₀ /Ag	1.05	21.60	77	17.46	17.8	0.0314	Combustion/150 °C	1
ITO/PLD-NiO/CH ₃ NH ₃ PbI ₃ /PCBM/LiF/Al	1.06	20.20	0.813	17.3	17.2	Non	PLD/ 200 °C	2
ITO/NiO/CH ₃ NH ₃ PbI ₃ /PCBM/Ag	1.07	20.58	0.748	16.47	16.22	0.07	Spin coating/ 130 °C	This work
ITO/NiO _x / CH ₃ NH ₃ PbI ₃ /ZnO/Al	1.01	21.00	76	16.1	Non	0.1	Spin coating/ 300 °C	3
FTO/Cu:NiO/CH ₃ NH ₃ PbI ₃ /PCBM/Ag	1.11±0.01	18.75±0.42	0.72±0.01	15.40±0.33	Non	Non	Spin coating/ 550 °C	4
FTO/TiO ₂ /ZrO ₂ /NiO/Carbon-(CH ₃ NH ₃ PbI ₃)	0.917	21.36	0.76	14.9	Non	Non	Doctor blade/500 °C	5
FTO/NiO _x /CH ₃ NH ₃ PbI ₃ /PCBM/Ag	1.09	17.93	73.8	14.42	14.18	0.07	Spin coating/ 500 °C	6
FTO/NiO/Meso-Al ₂ O ₃ /CH ₃ NH ₃ PbI ₃ /PCBM/BCP/Ag	1.04	18.0	72	13.5	13.61	0.09	Spray pyrolysis/ 500 °C	7
ITO/ NiO/meso-NiO/CH ₃ NH ₃ PbI ₃ /BCP/Al	0.96	19.8	61	11.6	Non	Non	Sputtering+spin coating/ 400 °C	8
FTO/TiO ₂ /NiO(CH ₃ NH ₃ PbI ₃)/Carbon	0.89	18.2	71	11.4	Non	0.6	Screen-printing/ 500 °C	9
FTO/ NiO NCs/CH ₃ NH ₃ PbCl _{3-x} I _x /PCBM (1.5 wt% PS)/Al	1.07	15.62	0.64	10.68	Non	Non	Spin coating/ 500 °C	10
FTO/NiO/CH ₃ NH ₃ PbI ₃ /PCBM/Ag	1.10	15.17	0.59	9.84	Non	Non	Sputtering/ No heated	11
FTO/NiO NCs/CH ₃ NH ₃ PbI ₃ /PCBM/Au	0.882	16.27	63.5	9.11	Non	Non	Spin coating/ 500 °C	12
ITO/NiO/meso-NiO/CH ₃ NH ₃ PbI ₃ /BCP/Al	1.04	13.24	69	9.51	Non	0.06	Spin coating/ 400 °C	13
ITO/NiO/CH ₃ NH ₃ PbI _{3-x} Cl _x /PCBM/BCP/Al	0.92	12.43	68	7.8	Non	0.06	Spun-cast/ 300 °C	14
ITO/NiO/CH ₃ NH ₃ PbI ₃ /PCBM/Al	1.05	15.4	48	7.6	Non	0.0725	Spin coating/ 350 °C	15
ITO/NiO/CH ₃ NH ₃ PbI ₃ /PCBM/BCP/Al	0.901	13.16	65.38	7.75	Non	0.06	Evaporation+annealing/ 450 °C	16
FTO/NiO /CH ₃ NH ₃ PbI _{3-x} Cl _x /PCBM/Ag	0.786	14.2	0.65	7.26	Non	0.07	Electrodeposited/ 350 °C	17

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