SUPPORTING INFORMATION

Structural and electrical investigation of Cobalt doped NiO_x/perovskite interface for efficient inverted solar cells

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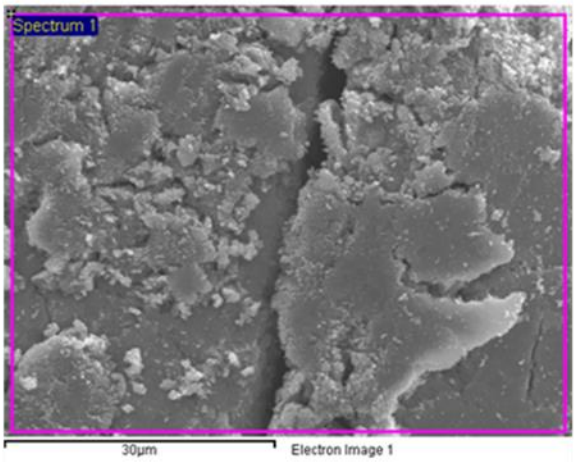
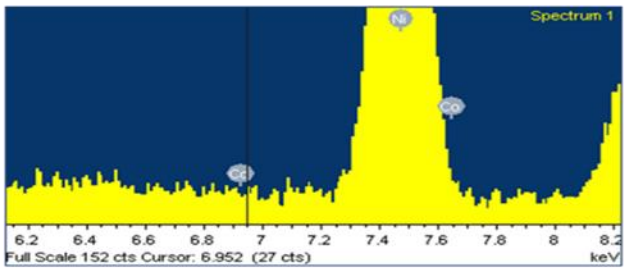
Table S1. Grain sizes (nm) of the pure NiO_x and different percentage Co doped nanoparticles, obtained from XRD measurement using the Debye-Scherrer formula $D_{XRD} = 0.89\ \lambda / \beta \cos\theta$, where λ is the incident X-ray wavelength (1.54 A), θ is the Bragg diffraction angle, β is the radian-based full width at half-maximum (FWHM) intensity of the peaks belonging to the XRD patterns in Figure 3a.

	NiO_x	0.75mol %	1mol %	1.25mol %	2.5mol %	5mol %
Grain size	17.1±0.4	12.4±0.3	11.9±0.2	12.1±0.2	12.3±0.3	11.5±0.2

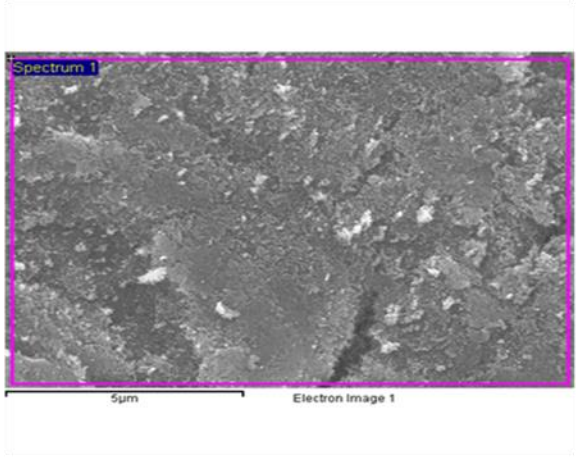
a)

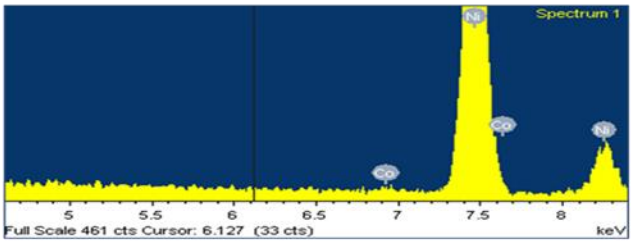




Element	Weight%	Atomic%	Compd%	Formula
Co K	0.00	0.00	0.00	CoO
Ni K	78.58	50.00	100.00	NiO
O	21.42	50.00		
Totals	100.00			

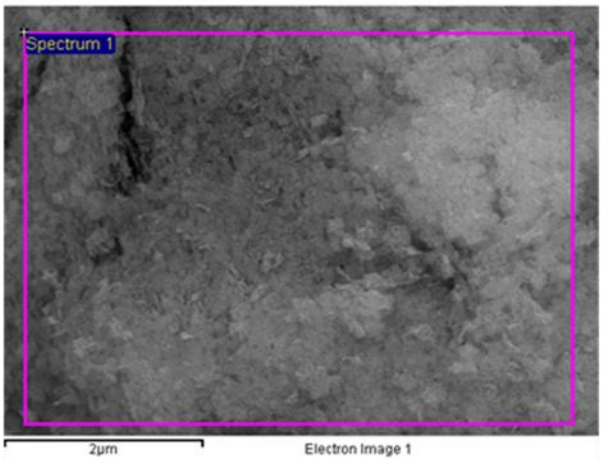
b)

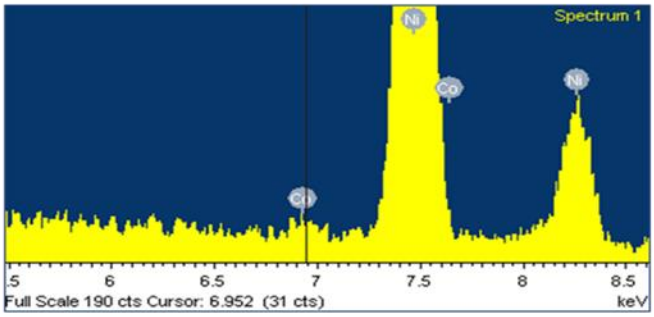




Element	Weight%	Atomic%	Compd%	Formula
Co K	0.55	0.35	0.70	CoO
Ni K	78.03	49.65	99.30	NiO
O	21.41	50.00		
Totals	100.00			

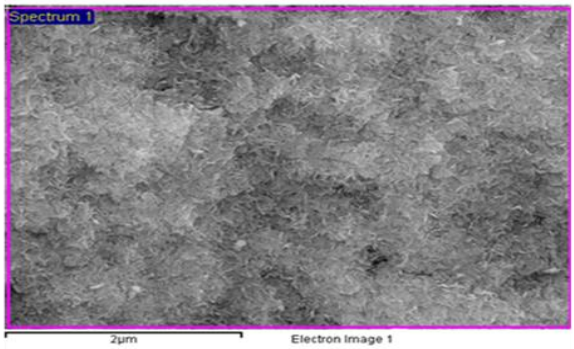
c)

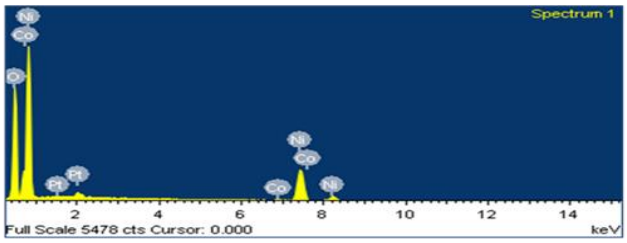




Element	Weight%	Atomic%	Compd%	Formula
Co K	0.92	0.58	1.17	CoO
Ni K	77.66	49.42	98.83	NiO
O	21.41	50.00		
Totals	100.00			

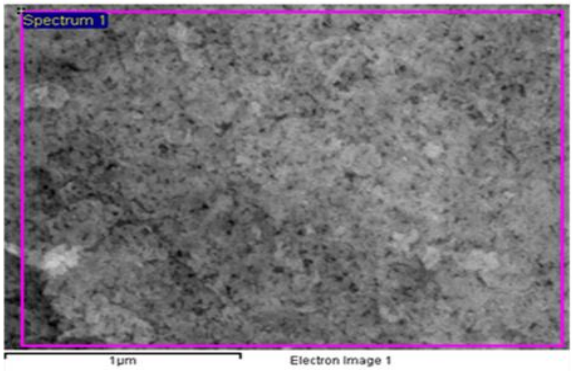
d)

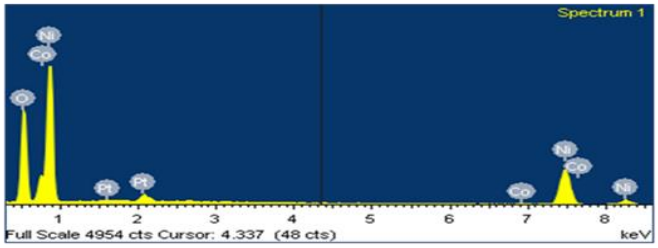




Element	Weight%	Atomic%	Compd%	Formula
Co K	1.09	0.69	1.38	CoO
Ni K	77.50	49.31	98.62	NiO
O	21.41	50.00		
Totals	100.00			

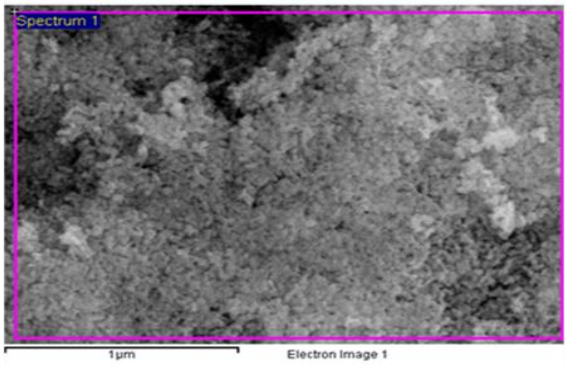
e)

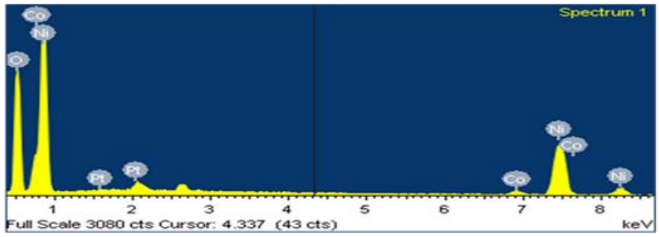




Element	Weight%	Atomic%	Compd%	Formula
Co K	2.09	1.33	2.66	CoO
Ni K	76.49	48.67	97.34	NiO
O	21.41	50.00		
Totals	100.00			

f)





Element	Weight%	Atomic%	Compd%	Formula
Co K	3.91	2.48	4.97	CoO
Ni K	74.68	47.52	95.03	NiO
O	21.41	50.00		
Totals	100.00			

Figure S1. EDS spectra for NiO_x and Co-NiO_x nanoparticles and quantitative analysis for each element (Ni, Co, O). a) NiO_x. b) 0.75 mol% Co-NiO_x. c) 1 mol% Co-NiO_x. d) 1.25 mol% Co-NiO_x. e) 2.5 mol% Co-NiO_x. f) 5 mol% Co-NiO_x.

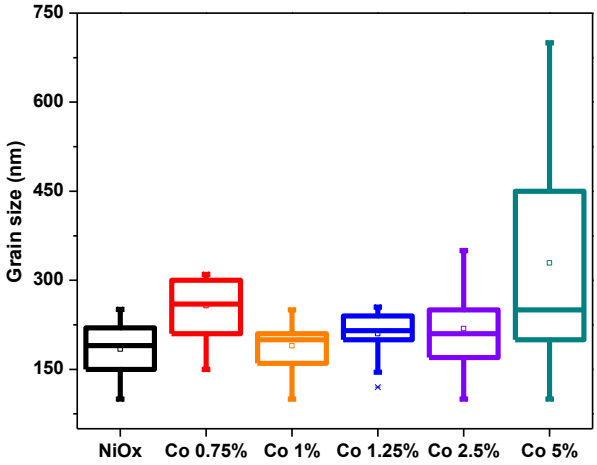


Figure S2. Perovskite grain size statistical distributions of the film deposited on the NiO_x with and without Co doping at different percentage (from 0.75 mol% to 5 mol%). The grain size is calculated with the SEM ruler for 40 grains of each kind of sample.

Table S2. Intensity of the XRD perovskite peaks (counts) and ratio between the intensitity of the peaks 110 (14.2 °) and 220 (28.5 °).

substrate	(110)	(220)	(110)/(220)
NiO_x	563	288	1.95
Co 0.75%	699	285	2.45
Co 1%	584	276	1.11
Co 1.25%	630	287	2.19
Co 2.5%	549	282	1.95
Co 5%	396	226	1.75

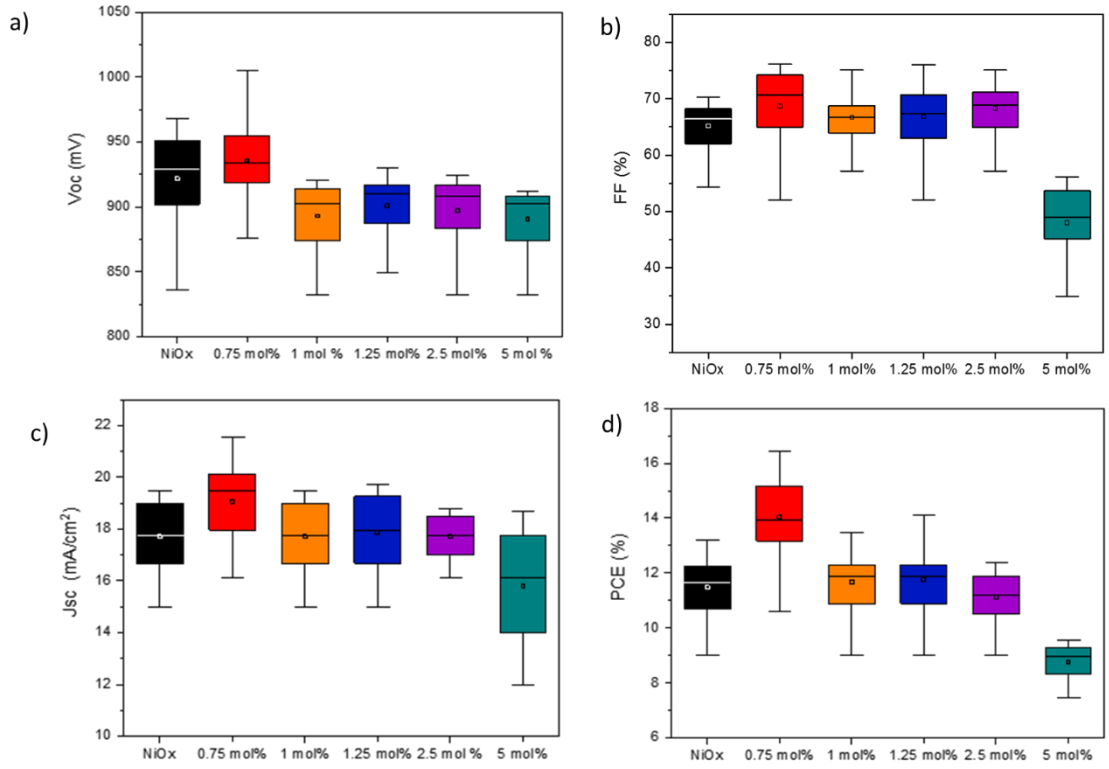


Figure S3. Statistical analysis of a) V_{oc} b) FF, c) J_{sc}, and d) PCE of 80 perovskite solar cells fabricated with 0-75-5% mol% Co-NiO_x and NiO_x.

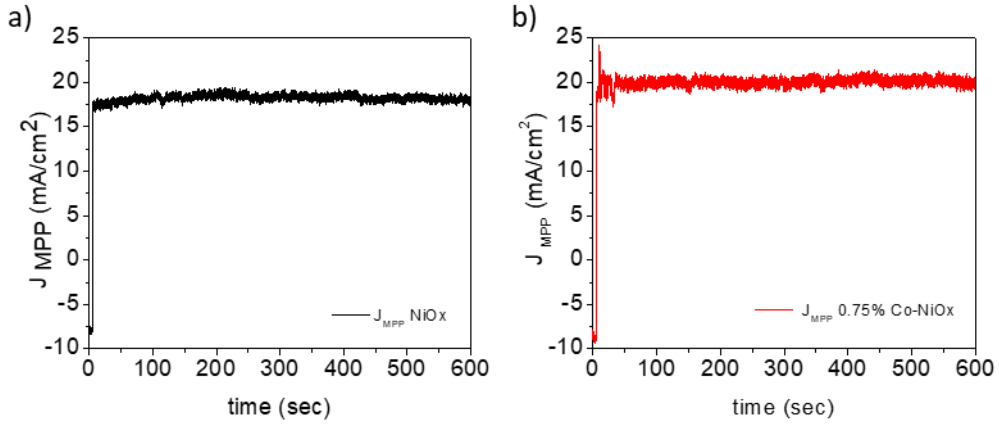


Figure S4. Recorded photocurrent at maximum power point J_{MPP} of the champion devices in the case of control NiOx and 0.75 mol% Co-NiOx based cells.

Table S3. Photoluminescence time decay parameters τ1 and τ2 and their average.			
	τ_1 (ns)	τ_2 (ns)	$\tau_{average}$ (ns)
$MAPbI_3$ on ITO	2.3	33	32
$MAPbI_3$ on NiO_x	1.6	20	20
$MAPbI_3$ on 0.75 mol% Co-NiO_x	0.8	10	9.8
$MAPbI_3$ on 1 mol% Co-NiO_x	0.9	9	8.5
$MAPbI_3$ on 1.25 mol% Co-NiO_x	1.8	11	10.3
$MAPbI_3$ on 2.5 mol% Co-NiO_x	2.1	14	12.5
$MAPbI_3$ on 5 mol% Co-NiO_x	1.5	13	11.2

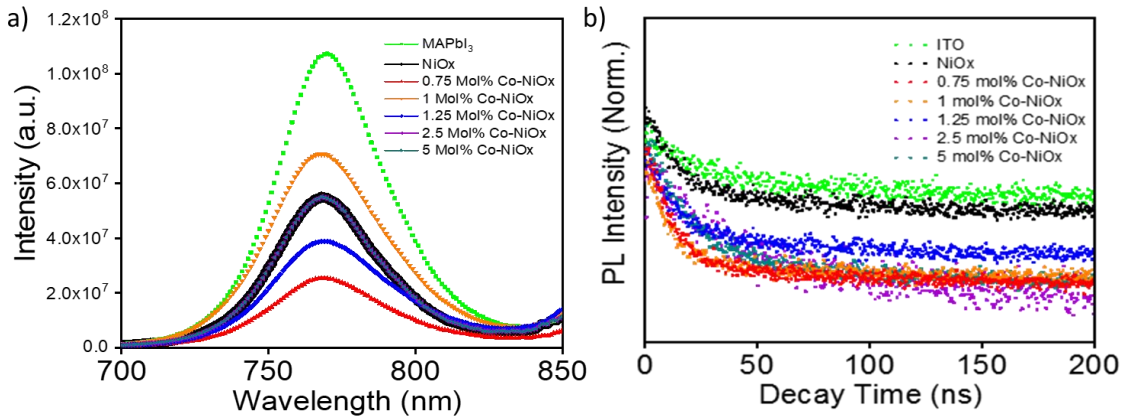


Figure S5. a) PL of $MAPbI_3$ films on top of NiO_x and 0.75-5 mol % Co-NiO_x. The $MAPbI_3$ on top of glass was used as a reference measurement; b) Time-resolves PL of the corresponding samples.

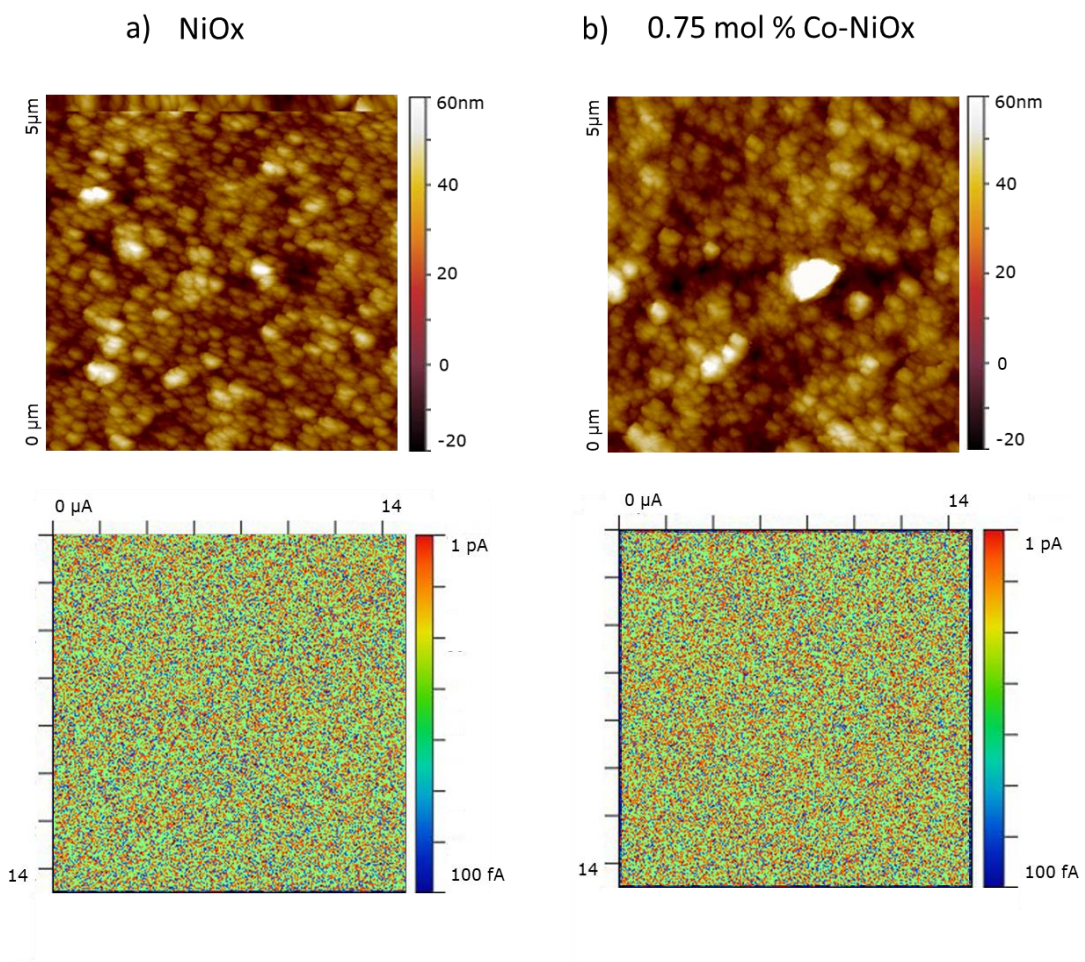


Figure S6. Conductive-AFM topographies on ITO substrates of a) pristine NiO_x and b) 0.75 mol% Co-NiO_x.