

Supporting Information for

Charge transfer doping of graphene oxide with nickel oxide nanoparticles for stable and efficient carbon-based, all-inorganic CsPbBr₃ perovskite solar cells

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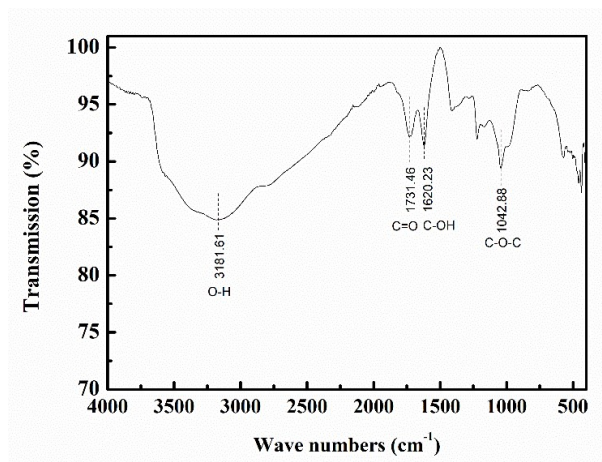


Figure S1. The FTIR spectrum of GO.

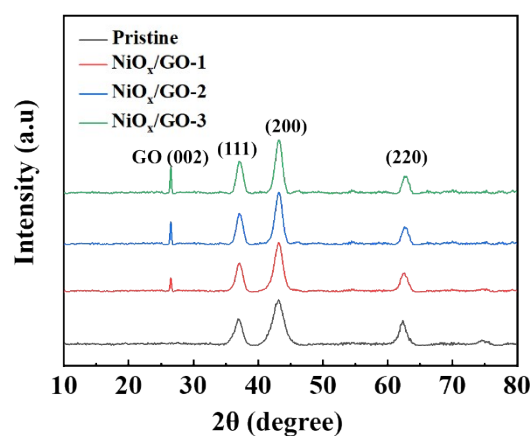


Figure S2. The XRD patterns of NiO_x nanoparticles, NiO_x/GO-1, NiO_x/GO-2 and NiO_x/GO-3.

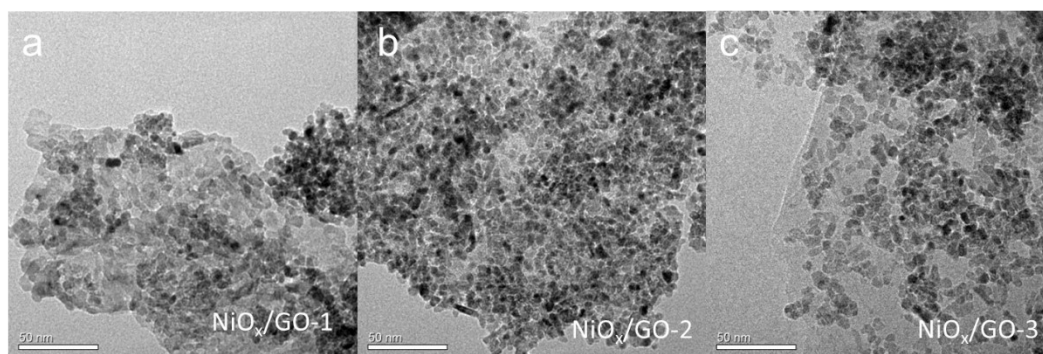


Figure S3. The TEM images of NiO_x nanoparticle decorated GO.

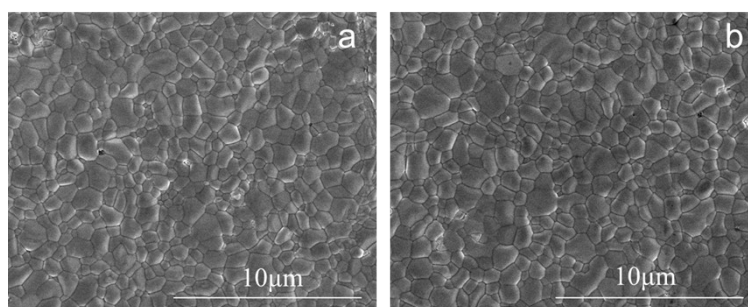


Figure S4. The SEM images of CsPbBr₃ (a) without and (b) with NiO_x/GO-2.

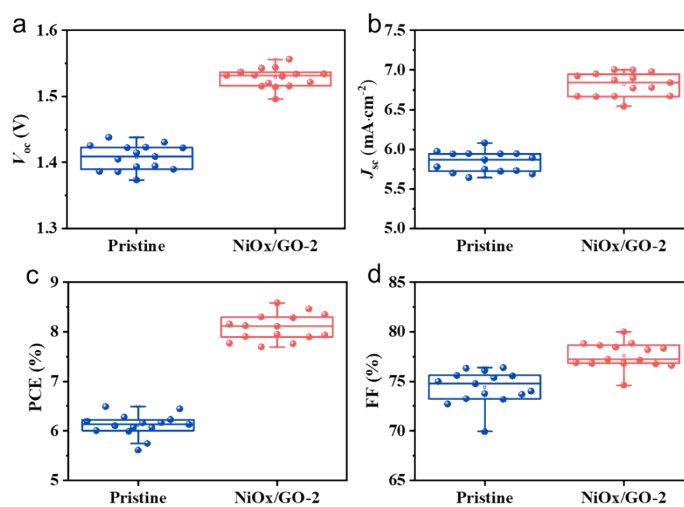


Figure S5. Box charts of photovoltaic parameters of (a) J_{sc} , (b) V_{oc} , (c) FF and, (d) PCE extracted from J-V measurements for the PSCs without and with NiO_x/GO-2.

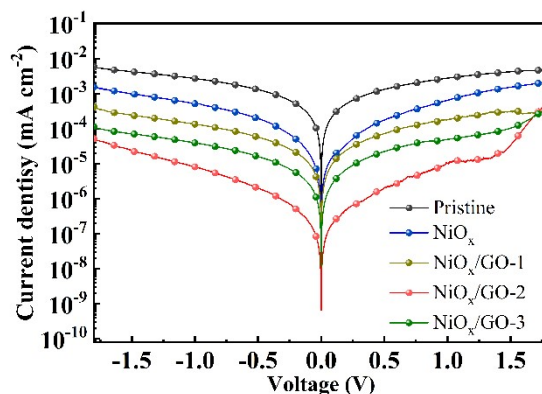


Figure S6 The J-V curves of various CsPbBr₃ PSCs in the dark.

Table S1. The dosages for preparing NiO_x decorated GO.

Sample	GO	Ni(NO ₃) ₂ ·6H ₂ O	H ₂ NCONH ₂
NiO _x /GO-1	0.0642 g	0.75 g	1.5 g
NiO _x /GO-2	0.1926 g	0.75 g	1.5 g
NiO _x /GO-3	0.7704 g	0.75 g	1.5 g

Table S2. The photovoltaic data for the all-inorganic CsPbBr₃ PSCs with different additives.

Samples	V _{oc} (V)	J _{sc} (mA·cm ⁻²)	PCE (%)	FF (%)	Ref
FTO/TiO ₂ /CsPbBr ₃ +Br-GO/Carbon	1.579	7.72	9.44	77.44	1
ITO/GO/CsPbBr ₃ /PEDOT:PSS/Au	1.57	8.50	10.34	77.40	2
ITO/SnO ₂ /CsPbBr ₃ /NiO/Au	1.57	7.57	7.15	77.44	3
ITO/TiO ₂ /CsPbBr ₃ /NiO/Au	1.11	8.65	4.04	41.98	4
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.46	8.12	9.6	81	5
FTO/TiO ₂ /CsPbBr ₃ /DAP/Carton	1.621	7.57	10.31	84.05	6
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.43	6.81	7.81	79.96	7
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.30	5.64	5.30	72.3	8
FTO/TiO ₂ /CsPbBr ₃ -thiourea/Carton	1.38	8.81	9.11	75	9
FTO/TiO ₂ /CsPbBr ₃ /UV-360/Carton	1.568	7.69	9.61	79.70	10
FTO/TiO ₂ /CsPbBr ₃ /Pt ₃ M Carton	1.520	6.77	7.62	74.05	11
FTO/TiO ₂ /CsPbBr ₃ -g-C ₃ N ₄ /Carton	1.277	7.80	8.00	80.32	12
FTO/TiO ₂ /T-CsPbBr ₃ /Carton	1.595	7.56	9.82	81.41	13
FTO/TiO ₂ /M-CsPbBr ₃ /Carton	1.584	7.42	9.65	82.11	14
FTO/TiO ₂ /CsPbBr ₃ -L-lysine/Carton	1.565	7.64	9.68	81.0	15
FTO/TiO ₂ /CsPbBr ₃ /[BMMIm]Cl/Carton	1.61	7.45	9.92	83	16
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.545	7.37	9.35	82.2	17
FTO/TiO ₂ /CsPbBr ₃ -PEG/Carton	1.41	7.56	7.8	73	18
FTO/TiO ₂ /CsPbBr ₃ -BiBr ₃ /Carton	1.39	7.83	8.73	80	19
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.15	7.65	5.84	66.3	20
FTO/TiO ₂ /CsPbBr ₃ /Carton-PANi/G	1.59	6.87	8.87	81.21	21
FTO/TiO ₂ /CsPbBr ₃ /ONC/CNT	1.33	5.55	5.87	80	22
FTO/TiO ₂ /CsPbBr ₃ -SnBr ₂ /Carton	1.37	7.66	8.63	82.22	23
FTO/TiO ₂ /CsPbBr ₃ /PVAc/Carton	1.540	7.28	8.62	76.91	24
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.34	6.46	5.86	68.04	25
FTO/TiO ₂ /CsPbBr ₃ -ZrO/Carton	1.44	7.75	8.19	73.52	26
FTO/TiO ₂ /CsPbBr ₃ -RPQDs/Carton	1.470	7.33	8.20	76	27
FTO/TiO ₂ /CsPbBr ₃ /CdZnSe@ZnSe/Carton	1.498	7.25	8.65	79.6	28
FTO/TiO ₂ /CsPbBr ₃ /Carton	1.20	5.3	3.9	64	29
FTO/TiO ₂ /CsPbBr ₃ /NiO _x /GO Carton	1.537	6.98	8.59	80.1	This work

Table S3. Photovoltaic data of the champion PSCs fabricated without and with NiO_x/GO.

Samples	J_{sc} (mA · cm ⁻²)	V_{oc} (V)	FF (%)	PCE (%)
Pristine	6.08	1.423	75.0	6.49
Pure NiO _x	6.28	1.442	69.6	6.30
NiO _x /GO-1	6.31	1.473	78.3	7.28
NiO _x /GO-2	6.98	1.537	80.1	8.59
NiO _x /GO-3	6.46	1.487	80.0	7.68

Table S4. Photovoltaic data for the pristine and NiO_x/GO-2 PSCs.

Samples	J_{sc} (mA · cm ⁻²)	V_{oc} (V)	FF (%)	PCE (%)
Pristine	5.84±0.13	1.407±0.019	74.4±1.7	6.11±0.22
NiO _x /GO-2	6.81±0.15	1.528±0.015	77.6±1.3	8.08±0.26

Table S5. The summary of carrier lifetime from TRPL analysis.

Samples	τ_1 (ns)	A ₁	τ_2 (ns)	A ₂	τ_{ave} (ns)
Pristine	0.069	73.67%	2.714	26.33%	0.156
Pure NiO _x	0.086	66.47%	3.799	33.53%	0.177
NiO _x /GO-1	0.090	68.8%	4.311	31.17%	0.186
NiO _x /GO-2	0.122	44.47%	4.730	55.53%	0.198
NiO _x /GO-3	0.073	74.75%	3.030	25.25%	0.161

Table S6. The summary of impedance from EIS analysis.

Samples	R _s (ohm · cm ²)	R _{rec} (ohm · cm ²)	CPE (nF · cm ²)
Pristine	3.77	13.6	86.3
NiO _x /GO-2	2.55	22.5	67.1

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