Supporting information for

In-situ Growth of α-$CsPbI_3$ Perovskite Nanocrystals on the Surface of Reduced Graphene Oxide with Enhanced Stability and Carrier Transport Quality

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Table S1. Structural parameters derived from the corresponding XRD patterns of α-$CsPbI_3$ NCs and α-$CsPbI_3$ NCs/rGO heterostructures. The crystal sizes of α-$CsPbI_3$ NCs are calculated by Debye-Scherrer equation. (Instrument correction value for instrumental broadening changes =0.1252 °)

	Full width at half maximum of (200) Peak, °	Calculated crystal size, nm
α-$CsPbI_3$ NCs	0.87	10.64
α-$CsPbI_3$ NCs/rGO	0.79	11.83

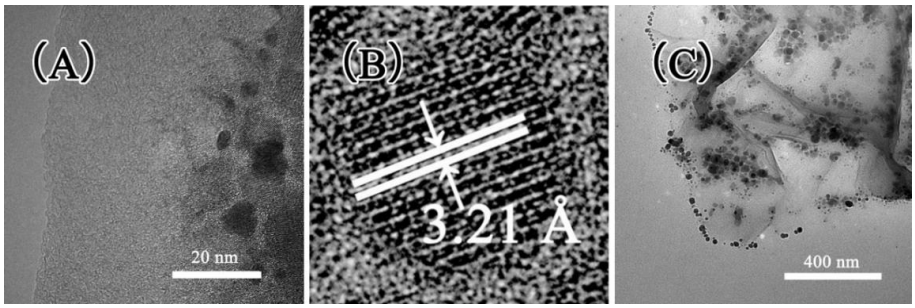

Figure S1. (A) TEM image of α-$CsPbI_3$ NCs/rGO heterostructures with a few Pb-nanoparticles appeared on the surface of rGO. (B) HRTEM image of α-$CsPbI_3$ NCs. The lattice figure of these NCs shows a value of ~3.21 Å, which is consistent with the crystal structure of α-$CsPbI_3$ perovskite. (C) TEM image of α-$CsPbI_3$ NCs/rGO heterostructures, and rGO was reduced by thermal-reduced reaction without FeI_2 treatment. Thus α-$CsPbI_3$ NCs showed a stochastic distribution on the surface of rGO and their shapes were not regular.

Table S2. Element contents derived from the corresponding XPS spectra of α-$CsPbI_3$ NCs and α-$CsPbI_3$ NCs/rGO. The element contents are normalized to investigate the effect of *in-situ* growth method on ligands amounts on the surface of α-$CsPbI_3$ NCs (Pb contents can be regarded as 1). It is clear that the amount of α-$CsPbI_3$ NCs obviously increased and the amount of C and O elements related to ligands significant decrease.

	α-$CsPbI_3$ NCs	α-$CsPbI_3$ NCs/rGO
Pb 4f	1.00	1.00
C 1s	63.11	17.37
N 1s	2.00	0.73
O 1s	25.04	1.71
I 3d	4.01	4.34
Cs 3d	1.00	1.23

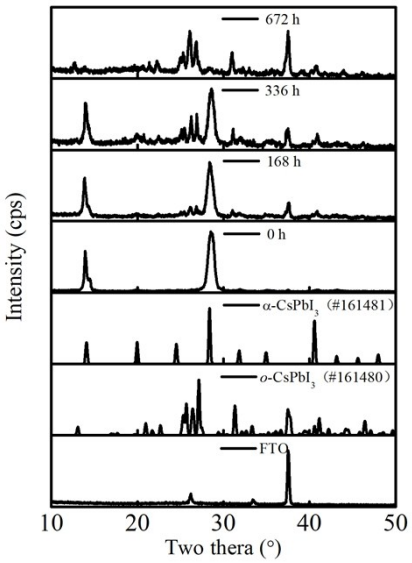

Figure S2. XRD patterns of α-$CsPbI_3$ NCs as a function of storage times stored in dark, low temperature (~4 °C) and low humidity (~1% RH) conditions without encapsulation. The recording storage times were ~0 h, ~168 h, ~336 h and ~672 h. The standard XRD patterns of FTO, *o*-$CsPbI_3$ (#161480) and α-$CsPbI_3$ (#161481) are also listed to identify the structural transitions of as-synthesized α-$CsPbI_3$ NCs. These XRD patterns showed that the α-$CsPbI_3$ NCs can easily transform into *o*-$CsPbI_3$ even when stored in dark, low temperature (~4 °C) and low humidity (~1% RH) conditions without encapsulation, completely losing their ideal crystal structure of optically active materials.

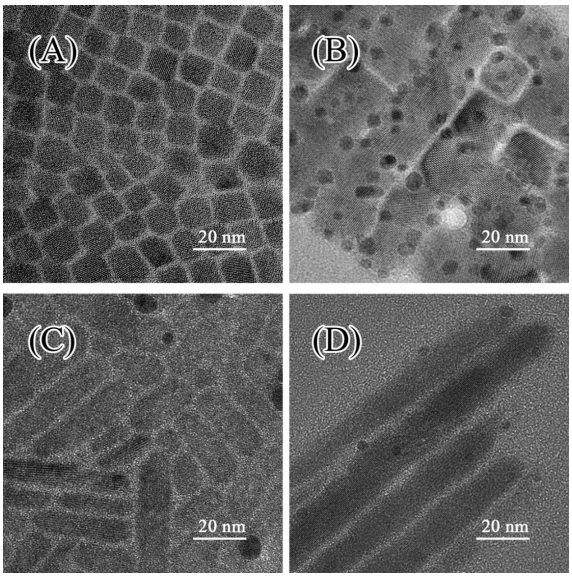

Figure S3. TEM images of α-$CsPbI_3$ NCs as a function of storage times stored in dark, low

temperature (~4 °C) and low humidity (~1% RH) conditions without encapsulation. The recording storage times were (A) ~0 h, (B) ~168 h, (C) ~336 h and (D) ~672 h.

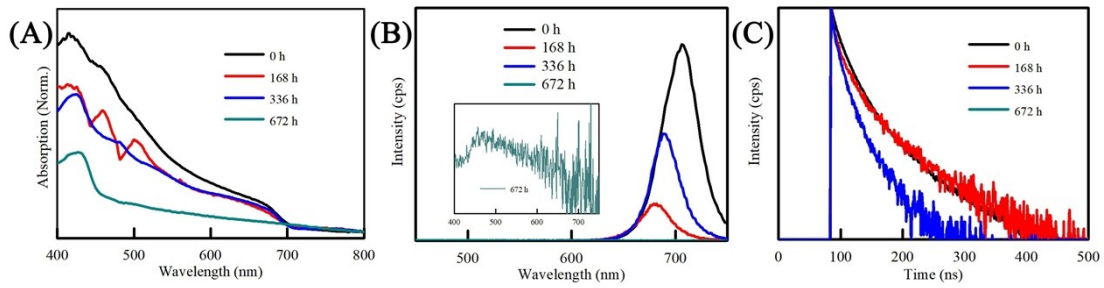

Figure S4. (A) UV-Visible absorption, (B) steady-state PL, and (C) time-resolved PL spectra of α-$CsPbI_3$ NCs as a function of storage times stored in dark, low temperature (~4 °C) and low humidity (~1% RH) conditions without encapsulation. The recording storage times were ~0 h, ~168 h, ~336 h and ~672 h. These UV-Visible absorption spectra showed a significant blue-shift of the absorption peaks when the storage time increased, thus narrowing their coverage of the visible region. Meanwhile, when the storage time increased, these PL intensities decreased and the PL bands showed a blue-shift, and their lifetime of α-$CsPbI_3$ NCs reduced. Particularly, when the storage time approaches ~672 h, the band gap of o-$CsPbI_3$ showed a value of ~2.64 eV, and the intensity of $CsPbI_3$ NCs almost disappeared, and their lifetime were hardly to detect in the testing conditions, completely losing their optoelectronic properties of optically active materials.

Table S3. Peak positions and Lifetime derived from the corresponding steady-state PL and time-resolved PL spectra of α-$CsPbI_3$ NCs as a function of storage times stored in dark, low temperature (~4 °C) and low humidity (~1% RH) conditions without encapsulation.

	Steady-state PL	Time-resolved PL			
	Peak position, nm	τ_1, ns	τ_2, ns	τ_3, ns	τ_{aver}, ns
0h	706.00	10.09	29.59	104.92	32.10
168h	688.00	7.49	29.40	97.74	25.45
336h	680.00	2.01	14.01	51.63	10.57
672h	-	-	-	-	-

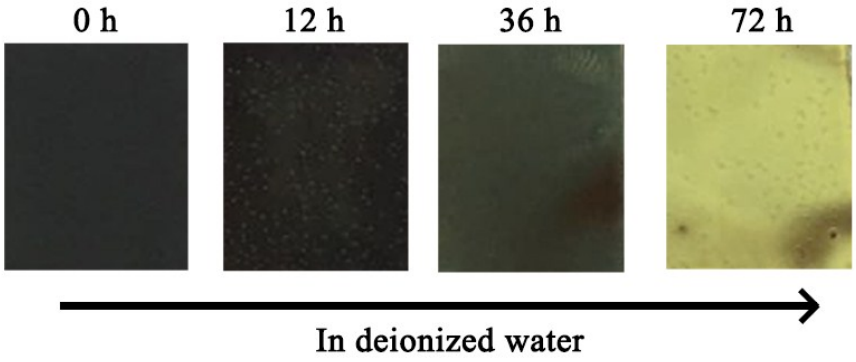

Figure S5. The color of α-$CsPbI_3$ NCs as a function of storage times placed in deionized water without encapsulation.

Table S4. Optoelectronic parameters derived from corresponding UV-Visible absorption, steady-state PL and time-resolved PL spectra of α-$CsPbI_3$ NCs and α-$CsPbI_3$ NCs/rGO heterostructures films.

	UV-Visible	Steady-state PL	Time-resolved PL			
	Band gap, eV	Peak Position, nm	τ_1, ns	τ_2, ns	τ_3, ns	τ_{aver}, ns
α-$CsPbI_3$ NCs	1.72	706.00	10.09	29.59	104.92	32.10
α-$CsPbI_3$ NCs/rGO	1.74	688.00	12.29	45.28	125.48	67.77

Table S5. Structural parameters and Lifetime derived from the corresponding XRD patterns and time-resolved PL spectra of α-$CsPbI_3$ NCs and α-$CsPbI_3$ NCs/rGO stored in ambient conditions (room temperature of ~25 °C and a humidity of ~25% RH conditions) for ~4 weeks without encapsulation. (Instrument correction value for instrumental broadening changes =0.1252 °)

	XRD		Time-resolved PL			
	Full width at half maximum of (200) Peak, °	Calculated crystal size, nm	τ_1, ns	τ_2, ns	τ_3, ns	τ_{aver}, ns
α-$CsPbI_3$ NCs	-	-	-	-	-	-
α-$CsPbI_3$ NCs/0.2-rGO	0.74	12.83	10.93	39.01	111.17	49.39

Table S6. PLQYs of α-$CsPbI_3$ NCs and α-$CsPbI_3$ NCs/rGO heterostructures films stored in ambient conditions for ~4 weeks without encapsulation.

	0 weeks, %	1 weeks, %	2 weeks, %	3 weeks, %	4 weeks, %
α-$CsPbI_3$ NCs	11.22	6.11	3.53	0.86	0.18
α-$CsPbI_3$ NCs/rGO	10.74	10.22	9.43	8.34	7.28