Supporting Information

Two-dimensional $Cs_3Sb_2Br_9$ Inducing Three-dimensional $CsPbBr_3$ Transformation to Nanoplates

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Experimental section

Chemical Materials. Cesium carbonate (Cs_2CO_3, 99.99%), lead bromide ($PbBr_2$, 99%), 1-octadecene (ODE, 90%), oleic acid (OA, 90%), oleylamine (OLA, 80-90%), antimony bromide hydrate ($SbBr_3$•xH_2O, 99%) and N,N-Dimethylformamide (DMF, 99.9%) were purchased from Aladdin. Toluene (99.5%) was purchased from Nanjing Chemical Reagent Co. Ltd. All materials and solvents were directly used without further purification.

Synthesis of Cs-OA. 0.8140 g Cs_2CO_3, 2.5 mL OA and 10 mL ODE were mixed into a 100 mL three-neck flask and dried under vacuum at 120 °C for 1 h. Then the mixture was heated to 150 °C under N_2 until the Cs_2CO_3 powders were completely dissolved to form a transparent solution. The solution was cooled down to room temperature in an ice-water bath and preheated to 120 °C before use.

Synthesis of $CsPbBr_3$ NCs. $CsPbBr_3$ NCs were synthesized by the following method. Cs-OA (0.04 mmol), $PbBr_2$ (0.10 mmol), OA (0.80 mmol) and OLA (0.40 mmol) were dissolved in 2 mL of DMF to prepare precursor solution. Then, 50 µL of the precursor solution was injected into 2 mL of toluene under vigorous stirring at room temperature. After the $CsPbBr_3$ crude solution was centrifuged at 5000 rpm for 3 min, we discarded the bottom sediment, the supernatant was used for further characterization.

Synthesis of $CsPbBr_3$ NPLs. $CsPbBr_3$ NPLs were synthesized by the following method. Cs-OA (0.04 mmol), $PbBr_2$ (0.10 mmol), OA (0.80 mmol) and OLA (0.40 mmol) were dissolved in 2 mL of DMF to prepare precursor solution. 0.1 mmol $SbBr_3$ was dissolved in 10 ml of toluene, which was diluted to different concentrations to tune Sb/Pb ratios. NPLs were prepared by injecting 50 µL of DMF precursor solution into different concentrations of $SbBr_3$ toluene solutions at room temperature with vigorous stirring. The centrifugation purification procedure was the same as that for $CsPbBr_3$ NCs.

Characterization. The chemical compositions were determined using a PerkinElmer NexION 2000 inductively coupled plasma mass spectrometer (ICP-MS). X-ray diffraction (XRD) data were collected using a Bruker D8 Advance X-ray powder diffractometer with Cu Kα radiation (λ = 0.154 nm). The morphology and size of NPLs were confirmed by transmission electron microscopy (TEM) (Hitachi, HT7700) and high-resolution TEM (HRTEM) (Talos, F200X). The ultraviolet-visible (UV-vis) absorption spectra were recorded using a PerkinElmer Lambda 35S instrument in transmission mode. Photoluminescence (PL) spectra were recorded using a RF6000 spectrofluorometer with an excitation wavelength of 400 nm. The PL lifetimes were measured using an FLS920 fluorescence spectrometer with a pulse laser at 375 nm. The photoluminescence fluorescence quantum yield (PLQY), which is defined as the ratio of emitted photons to absorbed ones, was determined using a FLS920 fluorescence spectrometer equipped with an integrating sphere.

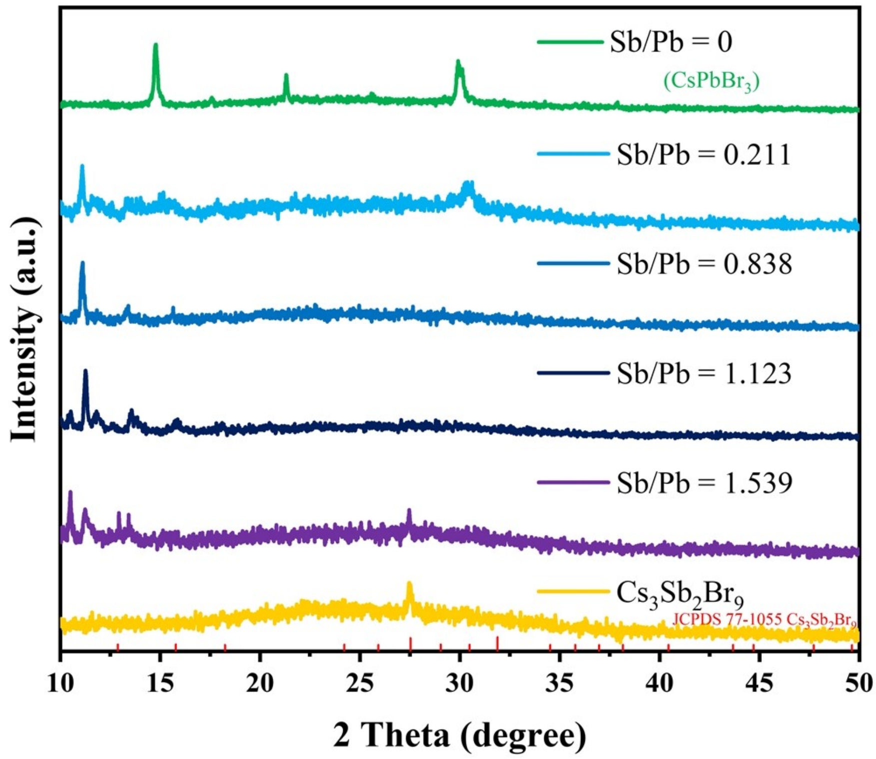

Fig. S1. XRD patterns of $CsPbBr_3$ and $Cs_3Sb_2Br_9$ samples with different Sb/Pb ratios.

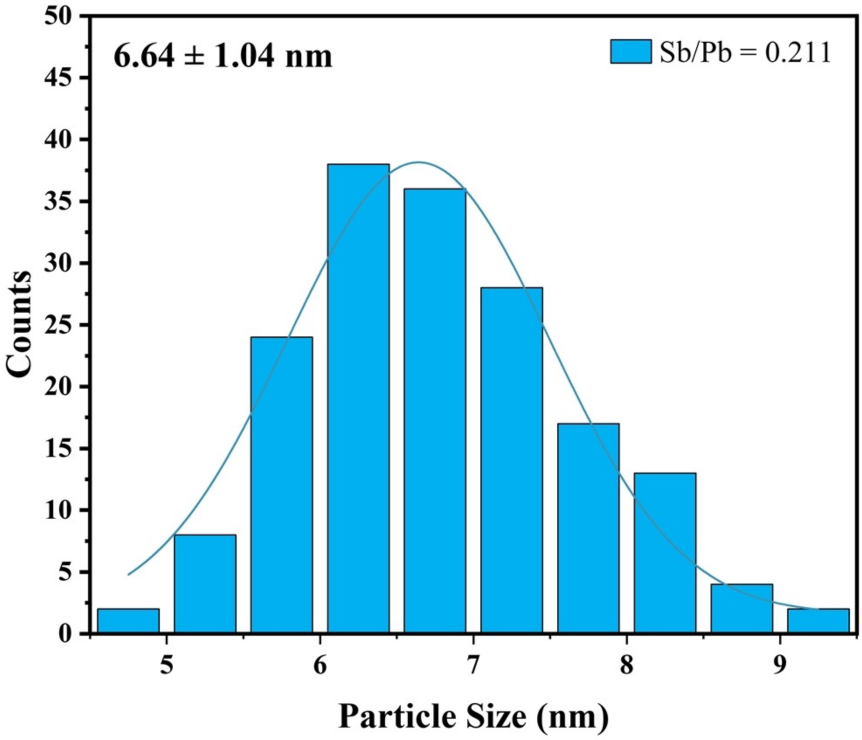

Fig. S2. Particle size distribution of $CsPbBr_3$ NCs (Sb/Pb = 0.211).

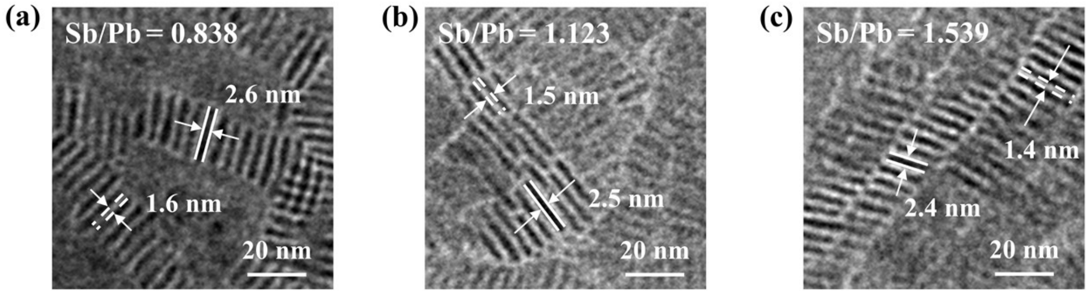

Fig. S3. Zoom-in TEM image of NPLs with different Sb/Pb ratios: (a) Sb/Pb = 0.838, (b) Sb/Pb = 1.123, and (c) Sb/Pb = 1.539.

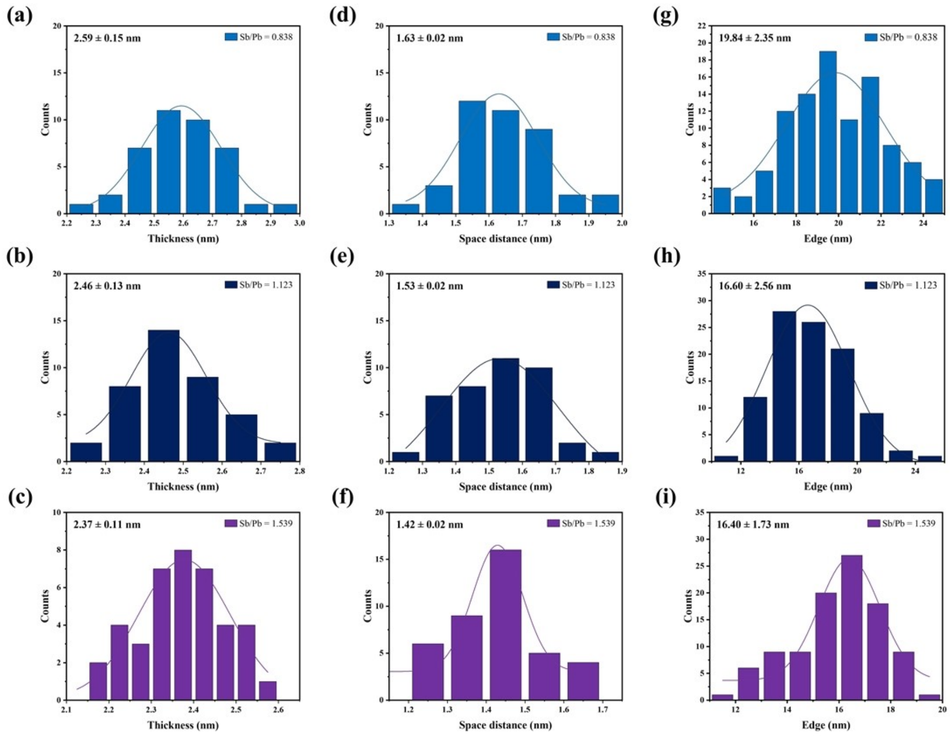

Fig. S4. Thickness (a-c), space distance (d-f), and edge (g-i) distributions for NPLs with different Sb/Pb ratios: (a), (d), (g) Sb/Pb = 0.838; (b), (e), (h) Sb/Pb = 1.123; and (c), (f), (i) Sb/Pb = 1.539.

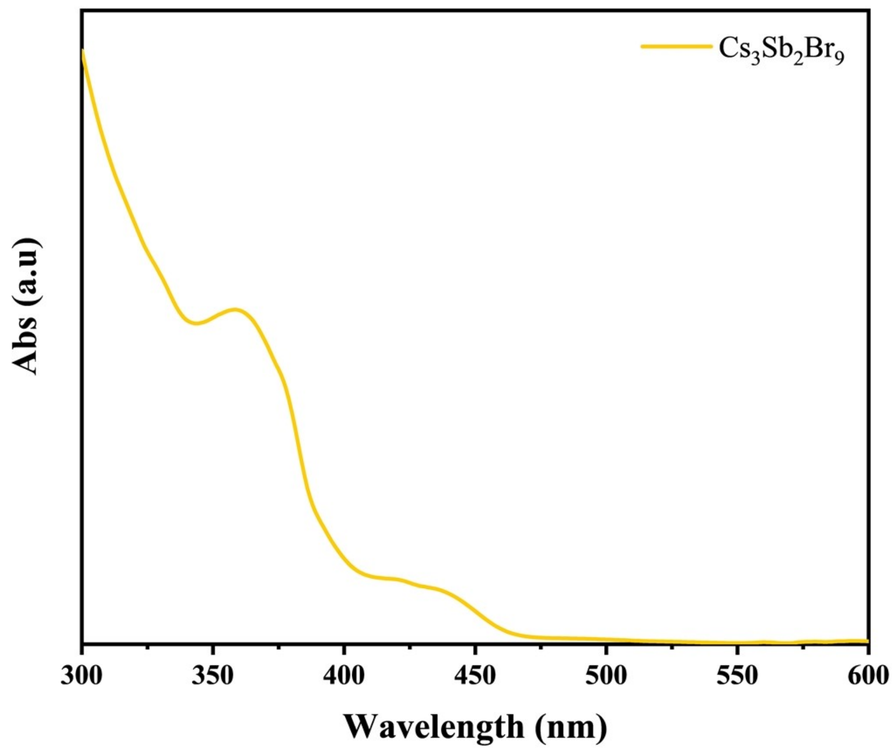

Fig. S5. UV-vis absorption spectrum for $Cs_3Sb_2Br_9$.

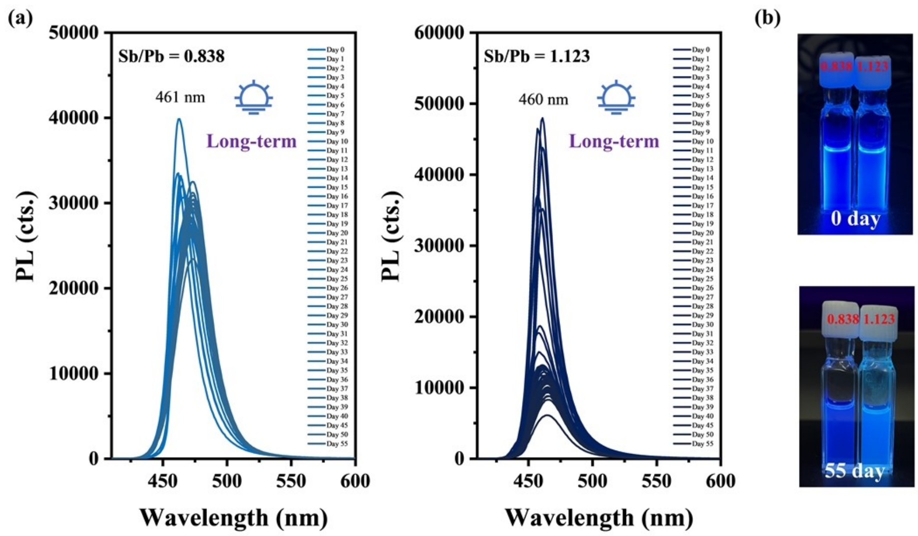

Fig. S6. (a) The long-term stabilities of deep blue NPLs: (left image Sb/Pb = 0.838 and right image Sb/Pb = 1.123). (b) The images of samples under UV light at 0 day and 55 days storage.

Fig. S7. The image of samples under sunlight at 55 days storage. (left image Sb/Pb = 0.838 and right image Sb/Pb = 1.123).

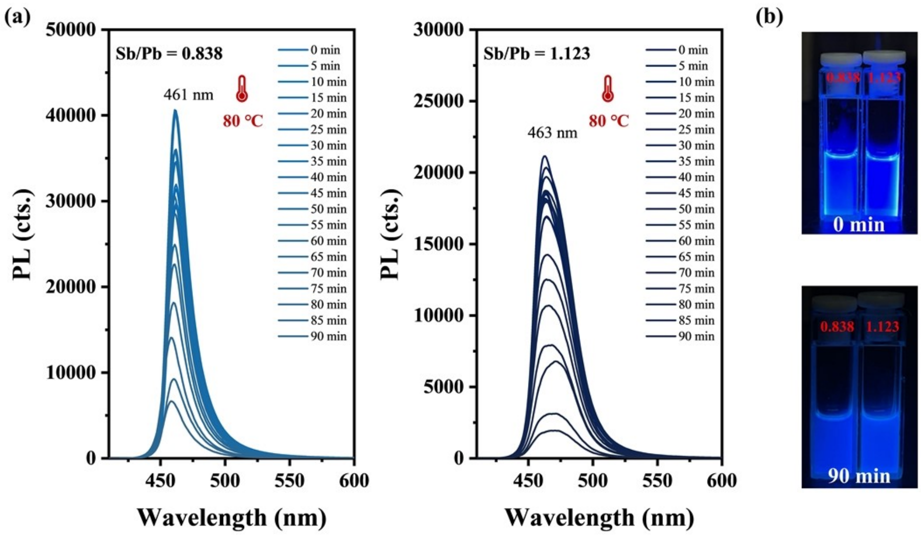

Fig. S8. (a) The thermal stabilities of deep blue NPLs at 80 ℃: (left image Sb/Pb = 0.838 and right image Sb/Pb = 1.123). (b) The images of samples under UV light at 0 min and 90 mins aging.

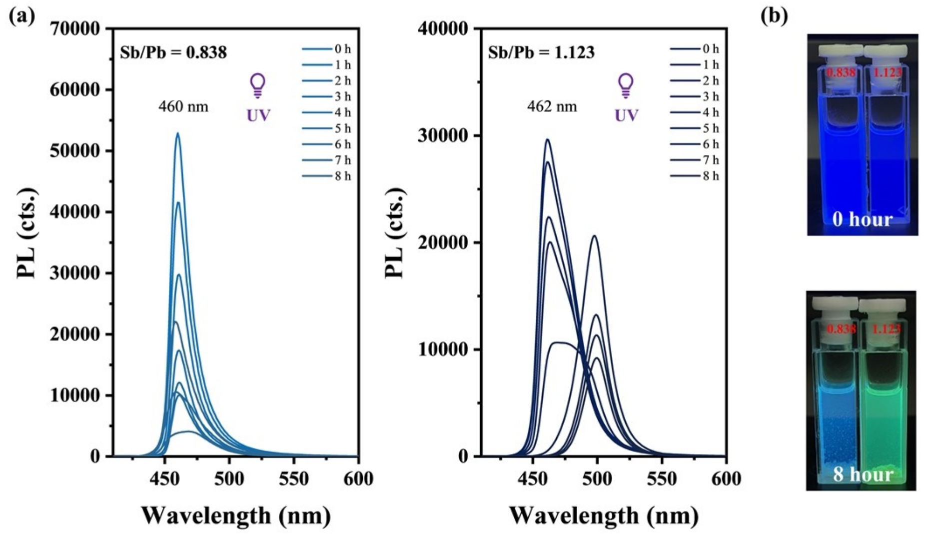

Fig. S9. (a) The UV resistance of deep blue NPLs under 365 nm (24 W) UV lamps: (left image Sb/Pb = 0.838 and right image Sb/Pb = 1.123). (b) The images of samples under UV light at 0 and 8 h aging.

Table S1. ICP-MS identification the actual Sb/Pb ratios.

Samples (feed Sb/Pb ratio)	Sb (ppb)	Pb (ppb)	Actual Sb/Pb ratio
B (0.5 : 1)	2.345	18.871	0.211 : 1
C (1.0 : 1)	4.644	9.438	0.838 : 1
D (1.5 : 1)	8.177	12.408	1.123 : 1
E (2.0 : 1)	11.292	12.492	1.539 : 1

Table S2. PL lifetimes of different Sb/Pb ratios.

Samples	Sb/Pb=0	Sb/Pb=0.211	Sb/Pb=0.838	Sb/Pb=1.123	Sb/Pb=1.539
τ_1 (ns)	3.96	4.94	5.50	4.01	1.24
τ_2 (ns)	15.30	10.69	12.14	12.31	5.86
A1	0.52	0.33	0.26	0.14	0.11
A2	0.48	0.67	0.74	0.86	0.89
τ_{avg} (ns)	9.40	8.79	10.41	11.14	5.35

Table S3. PL lifetimes of different Sb/Pb ratios. (average lifetime, τ_{avg}; nonradiative composite lifetime, τ_{nr}; radiative decay rate, k_r; radiative composite lifetime, τ_r; nonradiative decay rate, k_{nr}; and PLQY)

Samples	Sb/Pb=0	Sb/Pb=0.211	Sb/Pb=0.838	Sb/Pb=1.123	Sb/Pb=1.539
τ_{avg} (ns)	9.40	8.79	10.41	11.14	5.35
PLQY (%)	66	47	53	33	0.60
τ_r (ns)	14.24	18.70	19.64	33.75	891.67
k_r ($\times 10^{-2}$ ns^{-1})	7.02	5.34	5.09	2.96	0.11
τ_{nr} (ns)	27.64	16.58	22.14	16.62	5.38
k_{nr} ($\times 10^{-2}$ ns^{-1})	3.61	6.03	4.51	6.01	18.59
k_r/k_{nr}	1.94	0.88	1.12	0.49	0.01

Radiative recombination lifetime, $\tau_r=\tau_{avg}/PLQY$;

Non-radiative recombination lifetime, $\tau_{nr}=\tau_{avg}/(1-PLQY)$;

Radiative decay rate constant, $k_r=1/\tau_r$;

Non-radiative decay rate constant, $k_{nr}=1/\tau_{nr}$.