Electronic Supplementary Material (ESI) for Dalton Transactions.
This journal is © The Royal Society of Chemistry 2021

Supporting information

A Versatile Approach for Shape-Controlled Synthesis of Ultrathin Perovskite Nanostructures

Yongqiang Ji[a], Minqiang Wang*[a], Zhi Yang[a], Hengwei Qiu[a], Hui Wang[a], Muhammad Amin Padhiara[a], Yun Zhou[a], Jialin Dang[a], Nikolai V. Gaponenko[b], Arshad Saleem Bhatti[c]

[a]Electronic Materials Research Laboratory, Key Laboratory of the Ministry of Education International Center for Dielectric Research&Shannxi Engineering Research Center of Advanced Energy Materials and Devices, Xi'an Jiaotong University, 710049 Xi'an, China.

[b]Belarusian State University of Informatics and Radioelectronics, P. Browki St.6, 220013 Minsk, Belarus

[c]Centre for Micro and Nano Devices, Department of Physics, COMSATS Institute of Information Technology, Islamabad, 44500, Pakistan

Corresponding Author: E-mail: mqwang@xjtu.edu.cn

Experimental section

Materials and chemicals

The cesium carbonate (Cs_2CO_3, 99.99%), oleic acid (OA, 85%), oleylamine (OLA, 80-90%), octanoic acid (OctAc, 99%), octylamine (OctAm, 99%), trioctylphosphine (TOP, 97%), 1-octadecene (ODE, 90%) and Tetrabutylammonium iodide (TBA-I, 99%) were purchased from Aladdin. The lead(II) bromide ($PbBr_2$, 99.999%) was purchased from Xi'an Polymer Light Technology Corp. Tetrabutylammonium chloride (TBA-Cl, 95%) was purchased from Acros Organics. The toluene and ethyl acetate purchased from Shanghai Chemical Industrial Company. All the reagents were used without further purification.

Preparation of precursors.

Both precursors are obtained in air. In the Cs-OA precursor, a 30 mL bottle containing 0.4 g Cs_2CO_3, 15 mL of ODE, and 1.25 mL of OA, which was dried for 1 h at 120 °C under ambient until Cs_2CO_3 had reacted with OA sufficiently to get Cs-OA precursor. In the another precursor, a 30 mL bottle containing 0.367 g $PbBr_2$, ODE (10.0 mL), OA (0.5 mL), OLA (1.0 mL), OctAc (0.5 mL), OctAm (1.0 mL) and TOP (1.0 mL), which was dried for 1 h at 120 °C until solution become clear, then cooled naturally to room temperature at amibent conditions. Finally, the resulting solution is collected in a inert gas filled vial tightly covered with septum.

Synthesis of $CsPbBr_3$ perovskite nanosheets

$CsPbBr_3$ perovskite nanosheets (NSs) were synthesized by mixing hot precursors directly in air. Namely, the precursor of $PbBr_2$ and Cs-oleate (Cs-OA) are obtained under ambient condition, then preheated to 90 °C, and finally mixed into the bottle with

90 °C for reaction. The mixed solution maintained different time for the required different nanostructures, then quickly cooled down to room temperature using an ice bath. The synthesis of nanobelts (NBs) is the same as the synthesis of NSs, without the participation of TOP, and other reaction conditions remain unchanged. Finally, the solution was transferred to a centrifuge tube and centrifuged at 5000 rpm for 5 min. The resulting precipitate was redispersed in toluene for further use.

Measurement and characterization

Morphologies and elements of the samples were investigated by field emission scanning electron microscopy (SEM, FEI Quatan FEG 250) equipped with an energy dispersive spectrometer (EDS) and transmission electron microscopy (TEM, JEOL JEM-2100. The photoluminescence (PL) spectra, PL quantum yields (PLQYs) and time-resolved PL (TRPL) decay curves were recorded on an Edinburgh Instruments FLS9 spectrometer. The ultraviolet-visible (UV-Vis) absorption spectra were recorded by PE Lambda 950. The x-ray diffraction (XRD) patterns were obtained using the DB-ADVANCE X-ray diffraction analyzer diffractometer. The particle size distribution studies were carried out using Zetasizer Nano ZSE. X-ray photoelectron spectroscopy (XPS) spectra were measured by a Thermo Fisher ESCALAB Xi^{+}.

Introduce and discuss bi-exponential fitting function, which can be written as

$$I = A_1 \exp\left(-\frac{t}{\tau_1}\right) + A_2 \exp\left(-\frac{t}{\tau_2}\right)$$

Where A_1, A_2 and A_3 are constants, t is time, and τ_1, τ_2, τ_3 represent the decay lifetimes. The average lifetime (τ_{ave}) can be calculated as follows

$$\tau_{avu} = \frac{A_1\tau_1^2 + A_2\tau_2^2}{A_1\tau_1 + A_2\tau_2}$$

Table 1 The tri-exponential fitting parameters of time-resolved PL decay curves for different samples.

	A_1(%)	τ_1(ns)	A_2(%)	τ_2(ns)	τ_{avg}(ns)
NPs	93.84	6.9907	6.16	41.6542	9.1259
NRs	62.78	6.3435	37.22	58.1147	25.6126
NSs	59.66	7.0505	40.34	67.2163	31.3213
NBs	64.55	7.2005	35.45	62.9902	26.9779

Table 2. Percentage of each elemental atom of the energy spectrum of different samples

	Cs (Atomic%)	Pb (Atomic%)	Cl (Atomic%)	Br (Atomic%)	I Atomic%)
NSs	14.87	19.72	0	65.41	0
NBs	21.49	19.94	0	58.57	0
Cl-Br in NBs	21.15	18. 08	38.45	22.32	0
I-Br in NBs	21.44	16.97	0	26.30	35.29

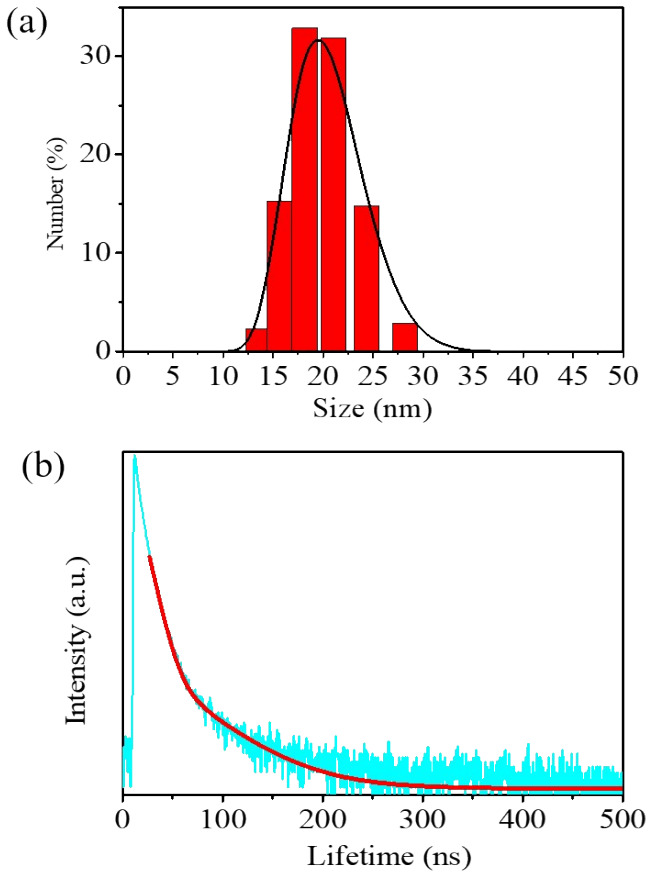

Fig. S1 Characterization of NSs. (a) The histogram of size analysis. (b) Time-resolved PL decay curve.

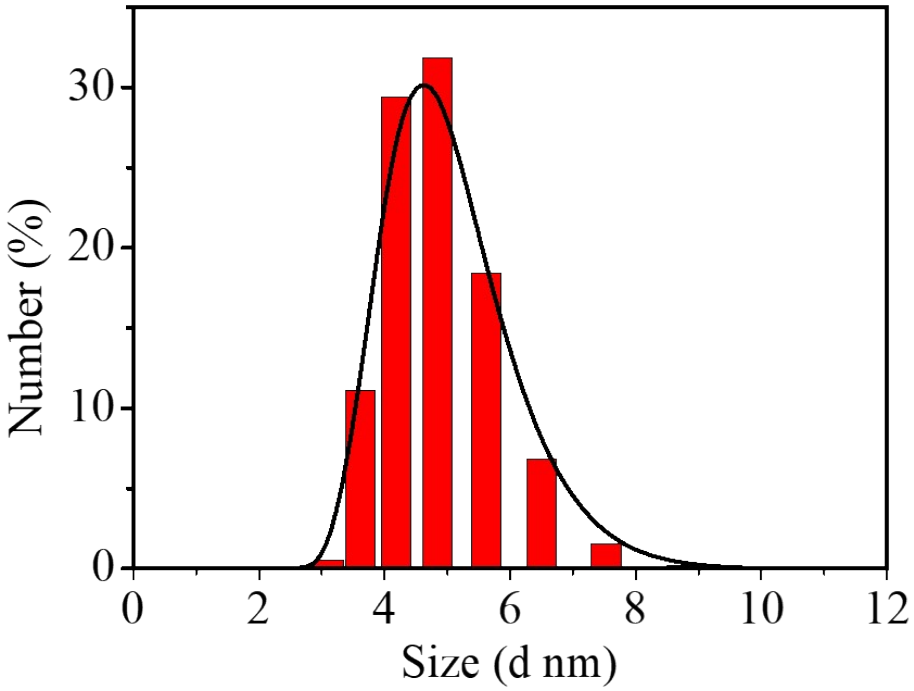

Fig. S2 The histogram of size analysis of nanoparticles

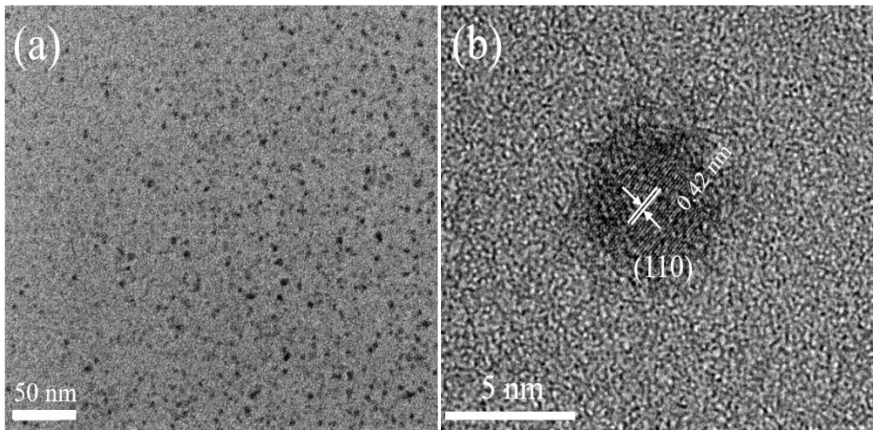

Fig. S3 (a) TEM image of NPs. (b) High resolution TEM image of NPs.

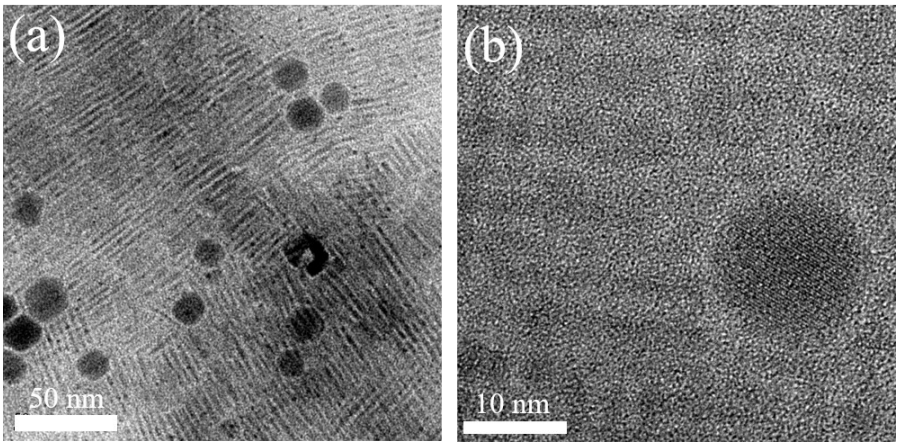

Fig. S4 TEM image of some larger spherical NPs coexist in these nanorods (NRs).

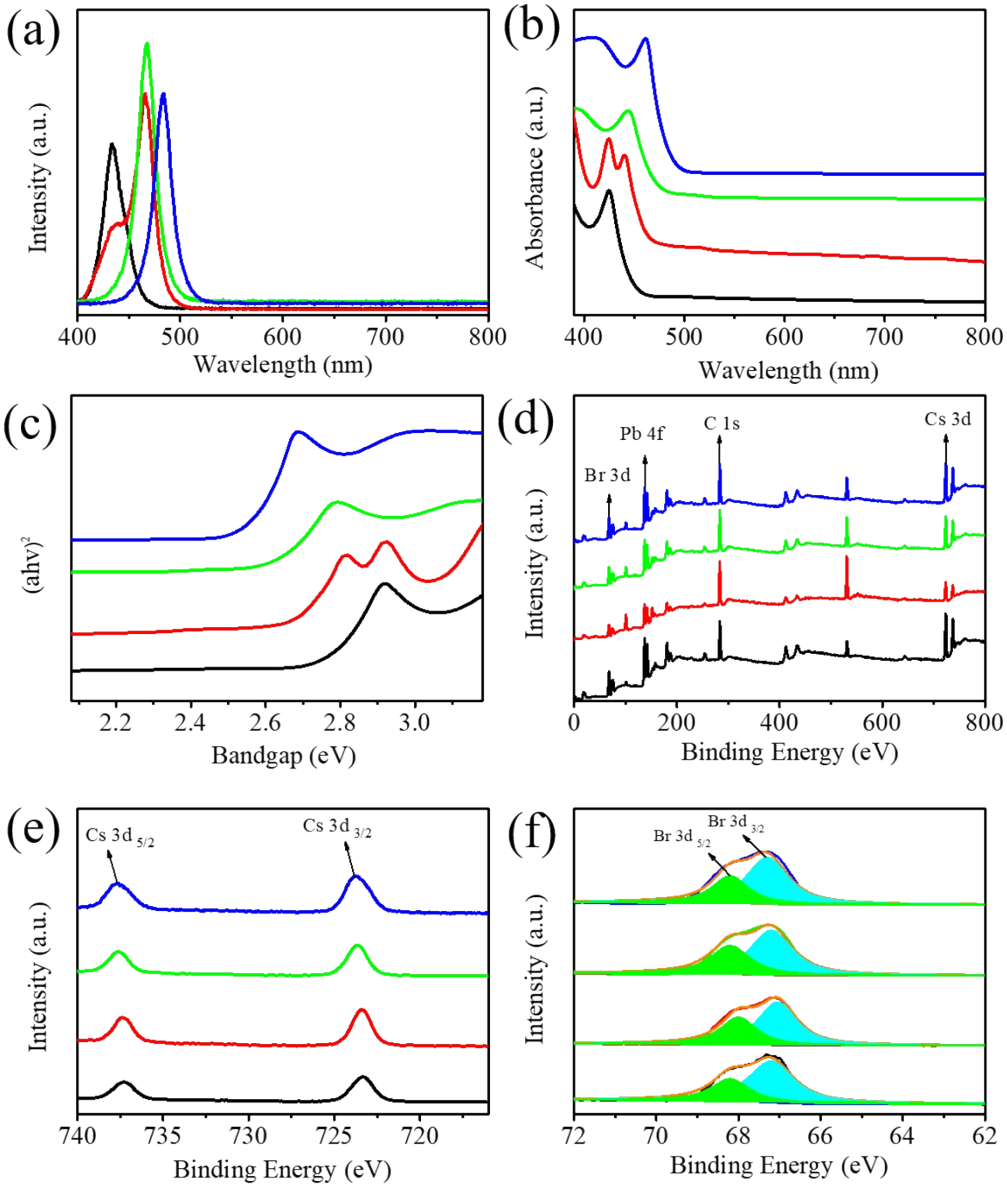

Fig. S5 (a) UV-Vis absorption spectra. (b) bandgaps. (c) PL spectra of the samples with variation of intensity. (d) XPS spectra (e) High resolution XPS of Cs 3d. (f) High resolution XPS of Br 3d. NPs (black). NRs (red). NSs (green). NBs (blue).

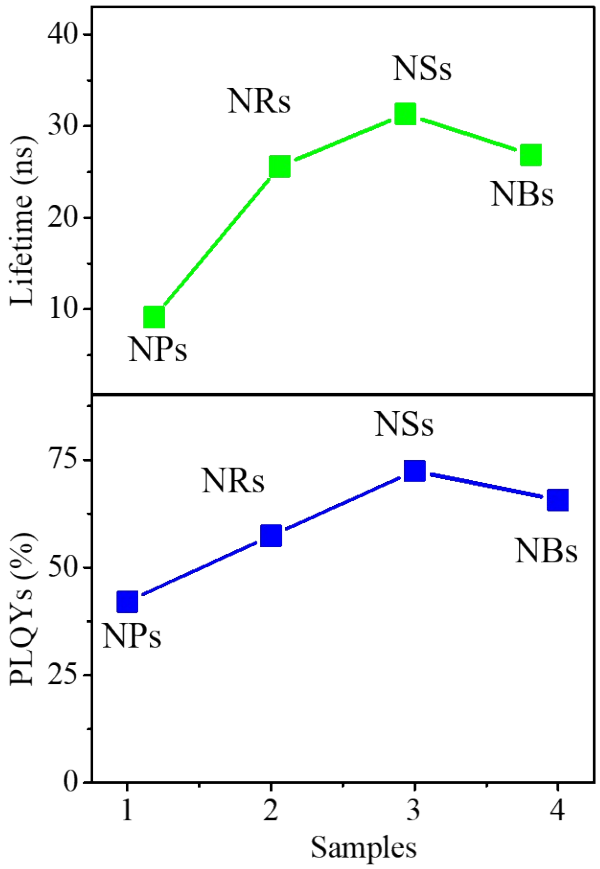

Fig. S6 PLQYs and PL lifetime of different sorts of samples.

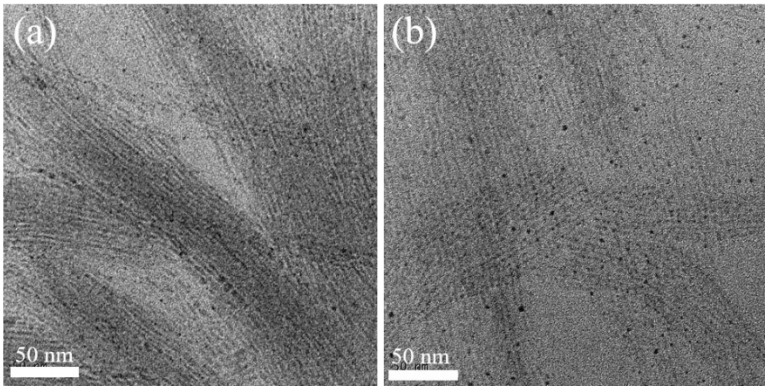

Fig. S7 TEM images of nanowires obtained during the upon dilution of these bundles.

(a) Bundles. (b) Nanowires.

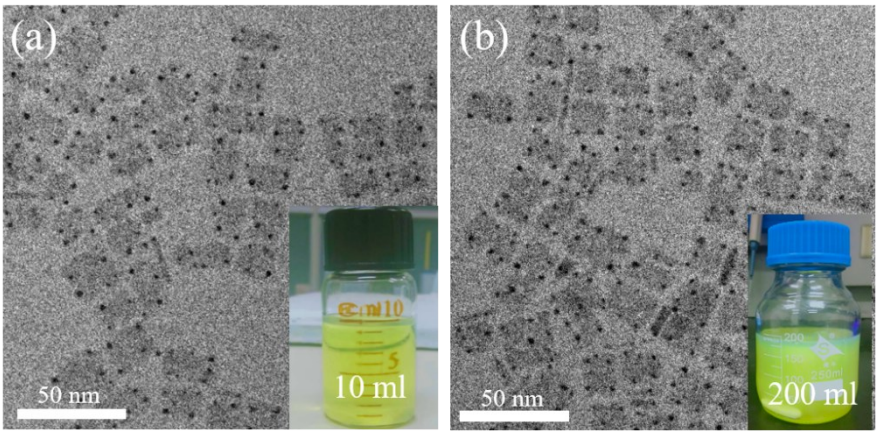

Fig. S8 TEM image of NRs. (a) Small batch synthesis. (b) Large batch synthesis. Inset. photo image of product synthesized under sunlight.

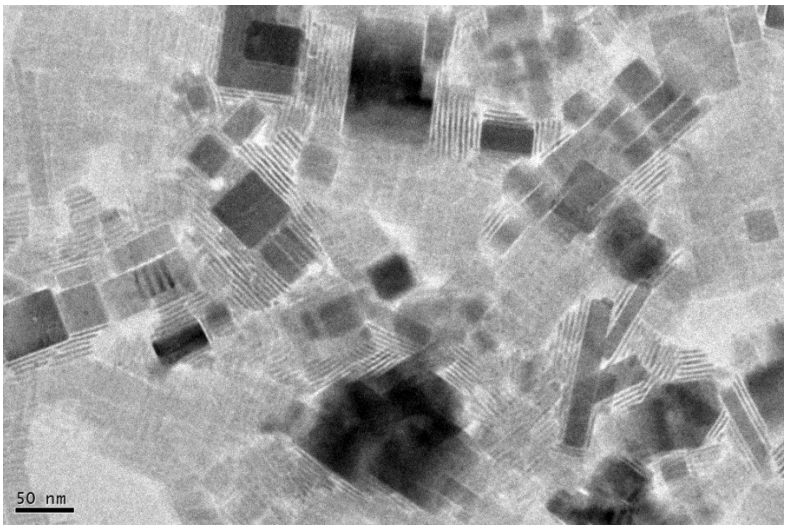

Fig. S9 TEM image of the perovskite NCs produced at 90℃ by the hot injection method with the continuous flow rate of nitrogen gas.

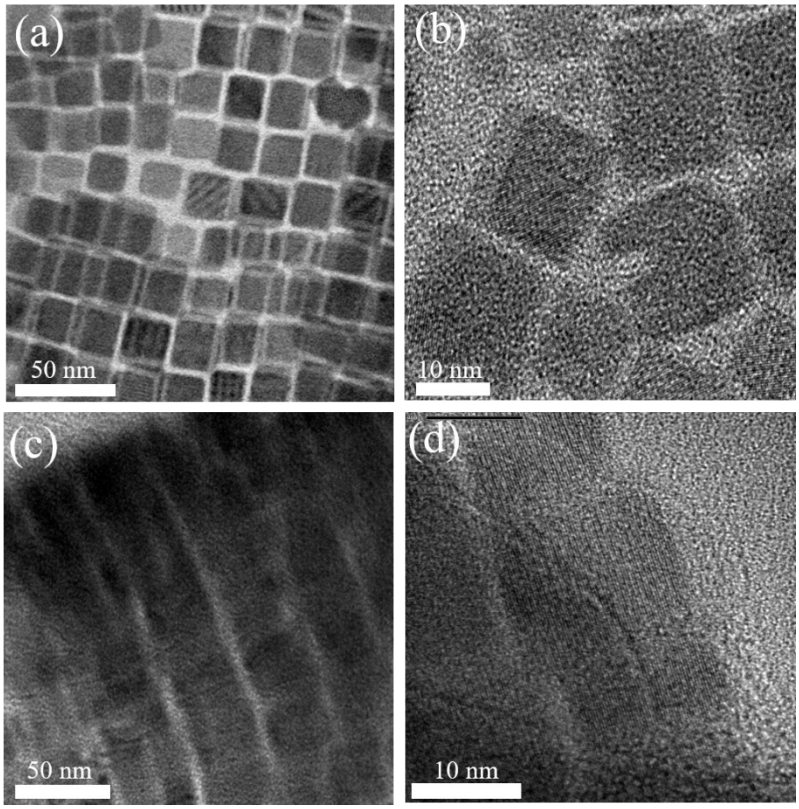

Fig. S10 (a-b) TEM image of the classic perovskite nanocrystals produced by the hot injection method with high flow rate of nitrogen gas. (a, b) nanocubes. (c, d) NBs.