Supporting Information

Optimizing CsPbBr3 Nanowires for High-Performance

Optoelectronics: Focusing on Blue Shift and Superfast Kinetics

through Amine-Rich Synthesis

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1. Materials and Synthesis Strategies

1.1 Materials

Lead bromide (PbBr₂, Aladdin, 99.9%), cesium carbonate (Cs₂CO₃, Aladdin, 99.9%), oleic acid (OA, Aladdin, 85%), 1-octadecene (ODE, Aladdin, 90%), octylamine (OAm, Aladdin, 70%), octylamine (OctAm, Aladdin, 99%), n-hexane (General Reagent, AR), ethyl acetate (General Reagent, AR), and molecular sieves (Aladdin, $4^{\dot{A}}$) were used in this study. OAm and octylamine were dehydrated using molecular sieves before use, while all other reagents were used as received without further purification.

1.2 Preparation of Cs-Oleate Solution

The cesium oleate solution was prepared by modifying the method developed by Protesescu et al.¹. In brief, 0.2 g of Cs_2CO_3 and 0.7 mL of oleic acid (OA) were placed in a three-neck flask, followed by the addition of 7.5 mL of 1-octadecene (ODE). The mixture was degassed and vacuum-dried at 120°C for 60 minutes. Afterward, it was heated to 150°C under nitrogen until the reaction between Cs_2CO_3 and OA was complete. The temperature was then lowered to room temperature, and the prepared Cs-oleate solution was stored in a glove box for later use. When needed, the solution was heated to 120°C for direct injection.

1.3 Synthesis and Purification of Perovskite Nanocrystals

To synthesize nanocrystals with a size of approximately 10 nanometers, the following procedure was followed: 8 mL of 1-octadecene (ODE), 0.069 g of PbBr₂, and 0.5 mL of OAm were placed in a 25 mL three-neck flask and vacuum-dried at 95°C for 45 minutes to form a milky white solution. Subsequently, the temperature was increased to 120°C under a nitrogen atmosphere. After maintaining this temperature for 30 minutes, 0.6 mL of the Cs-oleate solution (prepared as described earlier) was rapidly injected into the flask. The nanocrystals were allowed to grow at 120°C for 50 minutes, after which the reaction mixture was quickly cooled to room temperature using an ice water bath. The nanocrystals were separated from the unreacted OAm by centrifugation at 9000 rpm (8600 RCF) for 5 minutes. They were then redispersed in 2 mL of n-hexane and centrifuged again at 4000 rpm (1700 RCF) to collect the supernatant, which was stored for subsequent testing.

1.4 Synthesis and Purification of Perovskite Nanowires

To synthesize nanowires with a diameter of approximately 3 nanometers, the following procedure was used: 8 mL of 1-octadecene (ODE) and 0.069 g of PbBr₂ were loaded into a 25 mL three-neck flask and vacuum-dried at 95°C for 45 minutes, forming a milky white solution. Next, the temperature was raised to 120°C under a nitrogen atmosphere. At this point, 0.8 mL of pre-dried oleylamine (OAm) and 0.4 mL of octylamine (OctAm) were injected into the flask, and the reaction was held at 120°C

for 10 minutes before cooling to 65°C. Once the temperature stabilized at 65°C, 0.6 mL of Cs-oleate solution (prepared as previously described) was rapidly injected into the flask. The nanowires were allowed to grow at 65°C for 30 minutes, after which the reaction mixture was quickly cooled to room temperature using an ice-water bath. To purify the product, an equal volume of ethyl acetate was added to the crude solution (crude solution : ethyl acetate = 1:1). This mixture was then centrifuged at 11,000 rpm (12,840 RCF) for 10 minutes to remove unreacted oleylamine and octylamine. The nanowires were redispersed in 2 mL of n-hexane, bottled, and stored for further testing.

2、 Testing and Characterization

2.1 Material Morphology Characterization

Transmission Electron Microscopy (TEM) and High-Resolution Transmission Electron Microscopy (HRTEM): The size and morphology of the CsPbX₃ nanocrystals were characterized using transmission electron microscopy (TEM, JEOL-2100, Japan).

2.2 Material Structure Characterization

X-ray Diffraction (XRD) Analysis: The crystalline structure of the CsPbX₃ nanocrystal powder samples was examined using X-ray diffraction (XRD) on a Rigaku D/max-IIIB instrument, with Cu K α radiation at 40 kV and 40 mA.

2.3 Material Optical Property Characterization

Steady-State Absorption and Emission Spectroscopy: The UV-visible absorption spectra of CsPbX₃ (X=Cl/Br, Br, Br/I) nanocrystals and nanowires were recorded using a spectrophotometer (CARY100). Photoluminescence (PL) spectra were measured using a fluorescence spectrometer (Cary Eclipse) with a xenon lamp as the light source and an excitation wavelength of 365 nm.

Time-Resolved Photoluminescence (TRPL) Spectroscopy: Fluorescence lifetimes of CsPbX₃ nanocrystals and nanowires were measured on a spectrometer (FLS-1000) with a CCD detector, using a nanosecond laser as the light source and an excitation wavelength of 365 nm.

Transient Absorption (TA) Spectroscopy: The 800 nm femtosecond pulses generated by Ti: Sapphire laser (Coherent Libra) were led to an optical parametric amplifier (~50 fs, 1 kHz, OperA Solo from Coherent) to generate femtosecond pulses with variable wavelengths from 200 to 800nm and maximum average power of ~16 μ W. An idler light from optical parametric amplifier was used as the pump light, and the probe beam of white-light continuum generated by focusing the 800 nm laser beam onto a sapphire plate was used as the probe light. The 800 nm beam was led to an optical delay before focusing onto the sapphire plate. The probe light after transmitting the sample was focused into a monochromator and detected by a photomultiplier tube. The electronic signal from the detector was amplified by a lock-in amplifier (Stanford Research Systems: SR830) at the trigger frequency that is the same as the laser. During the data collection, samples were constantly moved to avoid the degradation of the samples at the excitation spot.



Fig. S1 TEM Images of Various Nanostructures Synthesized at 120°C with Different Ratios of OAm and OctAm:(a) 1 mL OAm, (b) 1.5 mL OAm, (c) 0.8 mL OAm, (d) 0.8 mL OAm and 0.4 mL OctAm.



Fig. S2 TEM images of various nanostructures prepared with 0.5 mL OAm at different temperatures (a) 100 $^{\circ}$ C, (b) 80 $^{\circ}$ C, (c) 65 $^{\circ}$ C, (d) 50 $^{\circ}$ C.



Fig. S3 TEM images of nanowires synthesized at 65° C for different reaction times (a) 60 min, (b) 20 min, (c) Nanowires obtained by pre-reacting oleylamine and octylamine for 30 min prior to degassing.



Fig. S4 TEM images of products synthesized with different amine component ratios. (a) Synthetic product with OAm: OctAm molar ratio = 1:1, (b) Synthetic product with OAm: OctAm molar ratio = 1:2.



Fig. S5 (a) Fast Fourier Transform (FFT) image of the NCs, (b) FFT image of the NCs with lattice spacings and angles indicated, (c) FFT image of the NWs, (d) FFT image of the NWs with lattice spacings and angles indicated.



Fig. S6 Normalized optical absorption (dashed black line) and photoluminescence of highly diluted CsPbBr₃ NWs solution (solid blue line).



Fig. S7 (a) PLQY measurement curve of CsPbBr₃ NWs; (b) PLQY measurement curve of CsPbBr₃ NCs, both tested under 365 nm light excitation.



Fig. S8 Fitting curves of bleaching kinetics for NWs and NCs.

 Table S1 Parameters of TRPL spectra for CsPbBr₃ NCs and CsPbBr₃ NWs were fitted

 using a bi-exponential function.

	$\tau_1(ns)$	$\tau_2(ns)$	A_1 %	A2%	$\tau_{ave}(ns)$
CsPbBr ₃ NCs	0.99	14.18	27.50	72.50	10.55
CsPbBr ₃ NWs	1.21	20.10	25.47	74.53	15.29

	τ ₁ (ps)	τ_2 (ps)	A ₁ %	A2%	τ _{ave} (ps)
CsPbBr ₃ NCs	7.75	36.27	34.67	65.33	26.38
CsPbBr ₃ NWs	10.57	54.68	49.40	50.60	35.84

Table S2 NWs and NCs bleaching dynamics curve fitting data.

References

Protesescu, S. Yakunin, M. I. Bodnarchuk, F. Krieg, R. Caputo, C. H. Hendon, R. X. Yang, A. Walsh and M. V. Kovalenko, *Nano Lett.*, 2015, 15, 3692–3696.