

Supporting Information

Stable deep blue FAPbBr₃ quantum dots facilitated by amorphous metal halide matrixes

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Experimental section

Chemical Materials. Formamidine acetate (FA-Ac, 99.9%), lead bromide (PbBr_2 , 99%), n-Octylamine (OTAm, 99%), octanoic acid (OTA, 99%), nickel bromide hydrate ($\text{NiBr}_2 \cdot x\text{H}_2\text{O}$, 96%) 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 FAPbBr₃ NCs. FAPbBr₃ NCs were synthesized by the following method. FA-Ac (0.12 mmol), PbBr_2 (0.3 mmol), OTA (3.6 mmol) and OTAm (0.18 mmol) were dissolved in 5 mL of DMF to prepare precursor solution. Then, 80 μL of the precursor solution was injected into 4 mL of toluene under vigorous stirring at room temperature. After the FAPbBr₃ crude solution was centrifuged at 5000 rpm for 3 min, we discarded the bottom sediment. 2 mL toluene was added into the supernatant, then the mixture was centrifuged 5 min at 12000 rpm. After discarding the supernatant, the precipitate was FAPbBr₃ NCs, which were redispersed into 2 mL toluene for further characterization.

Synthesis of FAPbBr₃ QDs based on metal halide matrix. FAPbBr₃ QDs were synthesized by the following method. In a typical ligand-assisted reprecipitation method, FA-Ac (0.12 mmol), OTA (3.6 mmol), OTAm (0.18 mmol) and different ratios of $\text{PbBr}_2/\text{NiBr}_2 \cdot x\text{H}_2\text{O}$ (Ni/Pb = 0, 0.5, 0.7, 1, 1.5, 2 and 2.75) were dissolved in 5 mL of DMF to prepare precursor solution. Then, 80 μL of the precursor solution was injected into 4 mL of toluene under vigorous stirring at room temperature. Centrifugal purification steps were the same as the steps of FAPbBr₃ NCs.

Characterization. The ultraviolet-visible (UV-vis) absorption spectra of QDs solutions were recorded using a PerkinElmer Lambda 35S instrument in transmission mode. PL spectra were recorded using a RF6000 spectrofluorometer with an excitation wavelength of 365 nm. The morphology and size of QDs were confirmed by transmission electron microscopy (TEM) (Hitachi, HT7700) and high-resolution TEM (HRTEM) (Talos, F200X). 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 K α radiation ($\lambda = 0.154$ nm). The PL lifetimes of QDs 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.

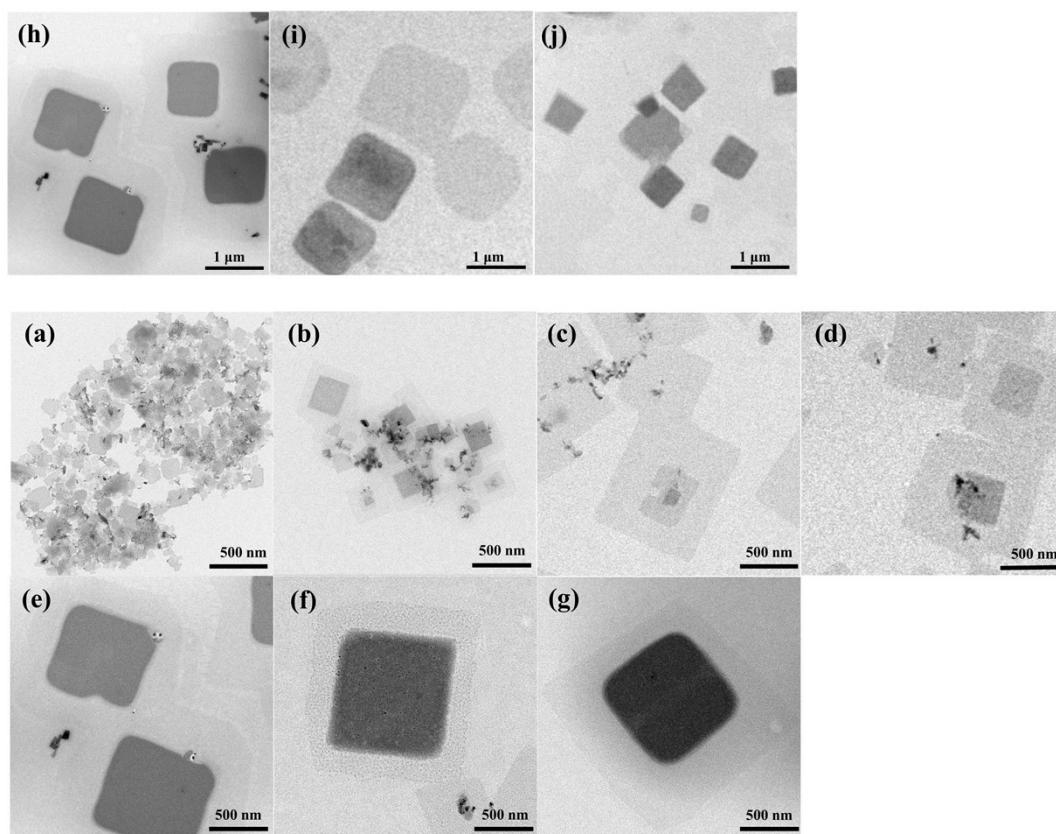


Figure S1. TEM images of FAPbBr₃ NCs and Ni²⁺-doped FAPbBr₃ QDs: (a) Ni/Pb=0, (b) Ni/Pb=0.44%, (c) Ni/Pb=0.60%, (d) Ni/Pb=0.80%, (e) Ni/Pb=1.36%, (f) Ni/Pb=4.86%, (g) Ni/Pb=7.96%. TEM images with larger scanning areas: (h) Ni/Pb=1.36%, (i) Ni/Pb=4.86%, (j) Ni/Pb=7.96%.

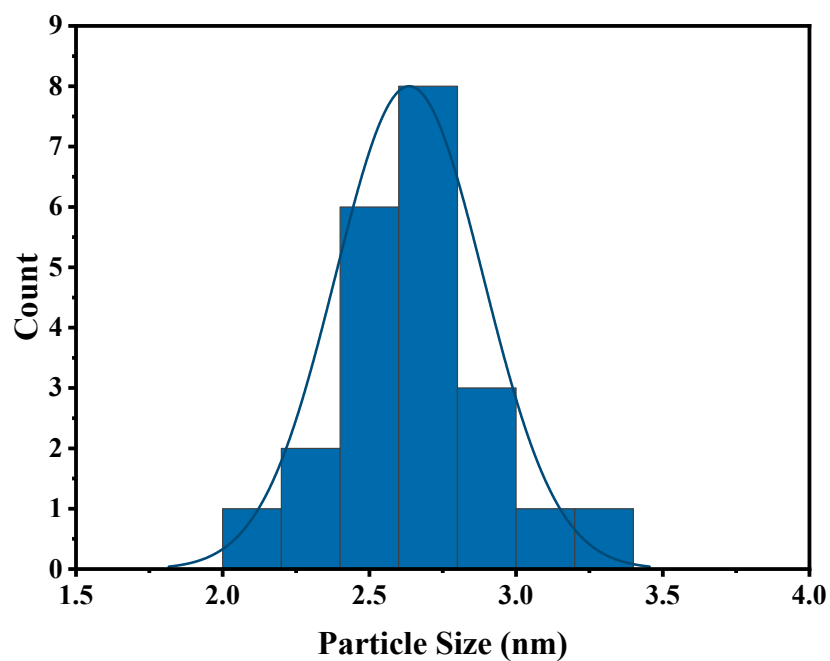


Figure S2. Particle size of deep blue FAPbBr₃ QDs. (Ni/Pb = 4.86%)

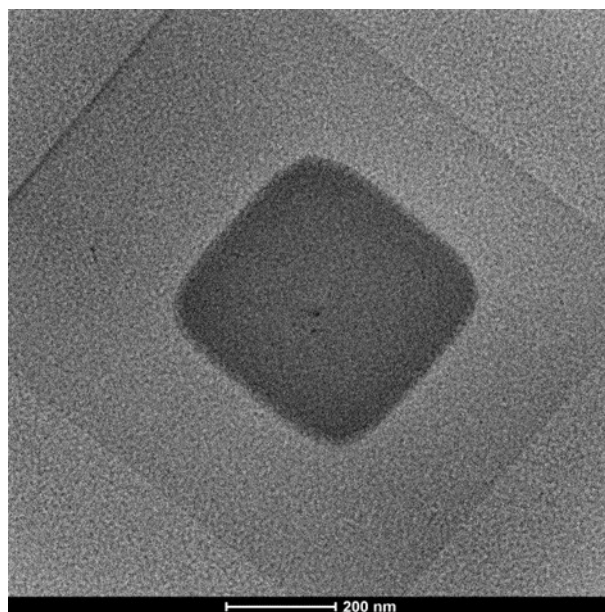


Figure S3. TEM images of deep blue FAPbBr₃ QDs (Ni/Pb=4.86%).

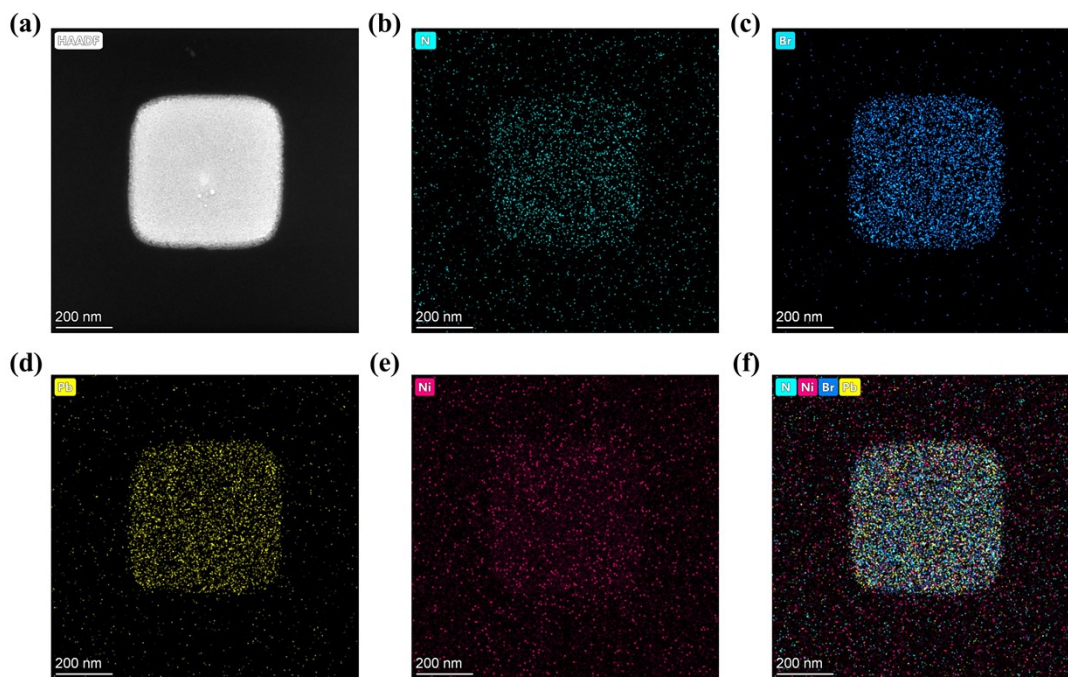


Figure S4. HAADF-STEM images of Figure S3 and the corresponding elemental mapping of N, Pb, Br, and Ni.

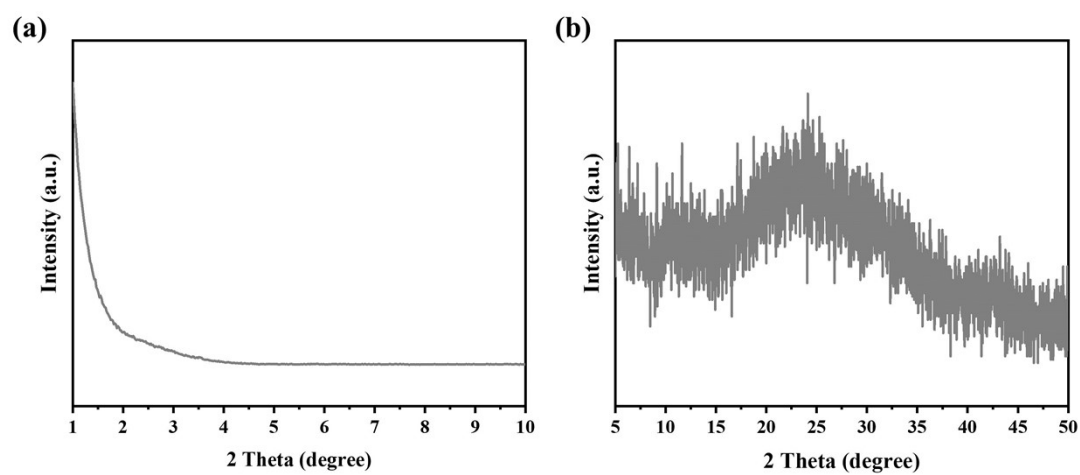


Figure S5. XRD patterns Ni^{2+} based metal halide matrix. (a) XRD patterns from 1-10°, (b) from 5-50°.

Table S1. The actual ratios of the Ni/Pb by ICP-MS for different Ni/Pb feed ratios

Samples	Ni (ppb)	Pb (ppb)	Actual Ni/Pb ratio
B	0.282	64.091	0.44%
C	0.411	68.500	0.60%
D	0.539	67.375	0.80%
E	0.729	53.603	1.36%
F	1.906	39.218	4.86%
G	4.802	60.327	7.96%

Table S2. PL lifetime of blue light component for Ni/Pb=4.86% and Ni/Pb=7.96%

Samples	Ni/Pb=4.86%	Ni/Pb=7.96%
τ_1 (ns)	0.70	0.74
τ_2 (ns)	5.98	6.32
τ_3 (ns)	65.19	56.04
A1	0.97 (60.6%)	0.98 (86.8%)
A2	0.10 (6.3%)	0.10 (8.8%)
A3	0.53 (33.1%)	0.05 (4.4%)
τ_{avg} (ns)	62.98	38.82