Supporting Information

Brightly-Luminescent and Color-Tunable Colloidal $\text{CH}_3\text{NH}_3\text{PbX}_3$ (X=Br, I, Cl) Quantum Dots : Potential Alternatives for Display Technology

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Table S1. Summary of the XRD analyses including miller index, 2 θ degree and lattice spaces.

QDs			Bulk		
(h k l)	2-theta	d (Å)	(h k l)	2-theta	d (Å)
(100)	14.76	5.99	(100)	14.94	5.93
(110)	20.32	4.36	(110)	21.19	4.19
(200)	29.78	2.99	(200)	30.15	2.96
(210)	33.55	2.66	(210)	33.82	2.65
(220)	42.70	2.12	(220)	43.18	2.09
(300)	45.50	1.99	(300)	45.94	1.97

Table S2. The elemental analysis. Br/Pb molar ratio of CH₃NH₃PbBr₃ QDs and CH₃NH₃PbBr₃ bulk material were determined by applying EDS characterizations. The proportion of methlamine and n-octalamine in QDs was extracted from XPS analysis.

Br/Pb molar ratio (Bulk)		Br/Pb molar ratio (QDs)	
atom	molar ratio (%)	atom	molar ratio (%)
Br	75.7	Br	77.8
Pb	24.2	Pb	22.1

Amine Percentage	
Amine	Percentage (%)
Methylamine	63.7
n-Octylamine	36.3

Table S3. Comparison of the structural and optical properties between $\text{CH}_3\text{NH}_3\text{PbBr}_3$ quantum dots and corresponding micrometer-sized particles.

Characteristics	Quantum dots	Micrometer sized particles
Surface	Br rich and capped with octylamine and oleic acid	—
Size	3.3 ± 0.7 nm	2-8 μm
Br/Pb atomic ratio	3.1	3.5
PL peak	515 nm	545 nm
FWHM	21 nm	~ 30 nm
PLQYs	50-70%	$<0.1\%$
PL lifetime	$\tau_1 = 6.6$ ns, 63.6%, $\tau_2 = 18.0$ ns, 36.4%	~ 100 ns (average)
Exciton binding energy	375 meV	65 meV
Phonon energy	42.2 meV	—

Table S4. Detailed information of halide substituted samples. The composition in the structural formula describes the initial molar ratio of halides.

Sample	$\text{CH}_3\text{NH}_3\text{PbX}_3$	Emission peak (nm)	FWHM (nm)	(x, y)
1	$\text{CH}_3\text{NH}_3\text{PbCl}_3$	373 407	37 34	(0.16, 0.04)
2	$\text{CH}_3\text{NH}_3\text{PbCl}_{2.1}\text{Br}_{0.9}$	446	17	(0.16, 0.03)
3	$\text{CH}_3\text{NH}_3\text{PbCl}_{0.6}\text{Br}_{2.4}$	467	32	(0.13, 0.08)
4	$\text{CH}_3\text{NH}_3\text{PbCl}_{0.3}\text{Br}_{2.7}$	493	29	(0.06, 0.39)
5	$\text{CH}_3\text{NH}_3\text{PbBr}_3$	515	22	(0.09, 0.73)
6	$\text{CH}_3\text{NH}_3\text{PbBr}_{1.2}\text{I}_{1.8}$	565	40	(0.43, 0.55)
7	$\text{CH}_3\text{NH}_3\text{PbBr}_{0.9}\text{I}_{2.1}$	610	50	(0.62, 0.38)
8	$\text{CH}_3\text{NH}_3\text{PbBr}_{0.4}\text{I}_{2.6}$	660	53	(0.68, 0.32)
9	$\text{CH}_3\text{NH}_3\text{PbI}_3$	734	45	(0.72, 0.28)

Table S5. The luminous efficiencies (LE), CIE coordinates (x, y), colour temperatures (T_c) of the as-fabricated LED devices operated at 2.64 V and 4.9 mA.

Device	Voltage (V)	Current (mA)	Luminous efficiency (lm/W)	(x, y)	T_c (K)
1	2.64	4.9	48.0	(0.33, 0.27)	5772
2	2.64	4.9	35.8	(0.37, 0.31)	3179
3	2.64	4.9	38.3	(0.44, 0.34)	2299
4	2.64	4.9	42.1	(0.39, 0.26)	2209
5	2.64	4.9	47.9	(0.31, 0.21)	4292
6	2.64	4.9	29.5	(0.38, 0.37)	3949

Figure S1. The optical images of typical $\text{CH}_3\text{NH}_3\text{PbBr}_3$ samples. a. the sample fabricated with oleic acid and n-octylamine stored for 30 days, b. the sample fabricated without adding oleic acid after 24 hours, c. the sample fabricated without oleic acid and n-octylamine.

Figure S2. SEM images of obtained $\text{CH}_3\text{NH}_3\text{PbBr}_3$ micrometer-sized particles.

Figure S3. comparison of XRD patterns between $\text{CH}_3\text{NH}_3\text{PbBr}_3$ QDs (red) and corresponding bulk material (black).

Figure S4. Schematic illustration of the structural model for $\text{CH}_3\text{NH}_3\text{PbBr}_3$ QDs.

Figure S5. Low temperature PL spectra of $\text{CH}_3\text{NH}_3\text{PbBr}_3$ QDs and corresponding bulk material obtained at different temperature, a. 10 K, b. 40 K, c. 80 K, d. 120 K. The significant raised region at long wavelength side of the PL emission peak of $\text{CH}_3\text{NH}_3\text{PbBr}_3$ bulk material (5 K) can be attributed to the trap meditative emissions. While the PL emission spectrum of $\text{CH}_3\text{NH}_3\text{PbBr}_3$ QDs is symmetric, indicating the absence of trap states. Meanwhile, with temperature increase, the trap states in bulk material became less noticeable and disappeared after 80 K.

Figure S6. The temperature dependence of (a) PL emission peak and (b) integrated PL intensity extracted from figure 5a-5c.

Figure S7. UV-Vis absorption and PL emission spectra of the halide substituted samples.

Figure S8. XRD patterns of halide substituted samples (No. 3-5, described in table S3).

Figure S9. TEM images of the Cl substituted samples (No. 1-4, described in table S3).