

Supporting Information

Perovskite nanostructures for photovoltaic and energy storage devices

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Table S1. Summary of metal halide perovskite nanostructures (organic-inorganic and all-inorganic) synthesized with ligand-assisted precipitation-based methods.

Chemical phase	Shape	Dimensions	Crystal structure	Capping agent	Reaction Temperature (° C)	Date	Ref
CH ₃ NH ₃ PbX ₃	nanospheres	6 nm	cubic	oleic acid, long alkyl ammonium cation	80	2014	1
MAPbBr ₃	nanoplates	Lateral: several hundreds of nm Thickness down to 1 nm	-	Oleic acid	30	2015	2
CH ₃ NH ₃ PbX ₃	nanospheres	3.3 nm	Cubic Br-rich surface	n-octylamine, and oleic acid (tested also longer alkylamine chains such as dodecylamine, hexadecylamine, and hexylamine and longer alkyl-acid chains such as octanoic acid, butyric acid)	30	2015	3
CH ₃ NH ₃ PbX ₃	nanodots, nanorods, nanoplates, nanosheets	CH ₃ NH ₃ PbI ₃ : Wires: 1500×34 nm Rods 810×54 nm Dots: 20 nm	CH ₃ NH ₃ PbBr ₃ : cubic	oleic acid, amine	30	2015	4

		CH ₃ NH ₃ PbBr ₃ wires: length 500 ×47 nm nanoplate s: 150×30 nm					
MAPbBr ₃	nanoplatelets	lateral: 430-520 thickness: 1-6 layers	-	oleic acid, alkylamine	30	2016	5
MAPbX ₃	nanocubes	MAPbCl ₃ : 21 nm MAPbBr ₃ : 25 nm MAPbI ₃ : 17 nm	MAPbCl ₃ , MAPbBr ₃ :c ubic MAPbI ₃ : tetragonal		30-120 depends on the chemical phase	2016	6
(C ₈ H ₁₇ NH ₃) ₂ (CH ₃ NH ₃) ₂ Pb ₃ (I _x Br _{1-x}) ₁₀ , 0 < x < 1	nanorods	~10nm	tetragonal	Octylammonium, oleic acid	30	2016	7
CsPbX ₃	nanocubes	~ 10 nm	monoclinic phase	Oleic acid, oleylamine	30	2016	8
CsPb ₂ Br ₅	nanoplatelets	~100-200 nm	tetragonal	hexylammonium	30	2016	9
CsPb ₂ Br ₅	nanosheets	Lateral: 7– 8 nm Thickness: 5nm	tetragonal	hexylamine	30	2016	10
CsPbX ₃	quantum dots, nanocube, nanorods, and nanoplatelets				25	2016	5
CsPbX ₃	quantum dots, nanoplates, nanobars, nanocubes, nanorods, nanowires demonstrated	quantum dots: 3nm nanoplatelets: 60 nm nanobars: length: 140 diameter: 55 nm nanocubes: 12 nm nanorods: length: 800nm Diameter 70nm nanowires: length: >15µm Diameter 70nm	quantum dots: cubic nanoplatelets: orthorhombic nanobars: orthorhombic nanocubes: cubic nanorods: orthorhombic nanowires: orthorhombic	Oleic acid, oleylamine	30	2016	11
CsPbBr ₃	nanoplatelets	lateral: 8 nm×41 nm thickness: 3-5 monolayer	cubic	oleic acid, oleylamine	30	2016	12

		s					
Cs ₄ PbBr ₆	quite spherical	26 nm	rhombohedral	oleic acid, oleylamine	30	2017	13
CsPbBr ₃	nanowires	length: μm width: 3-6 nm	orthorombic	oleic acid, oleylamine	0	2017	14
Cs ₄ PbBr ₆ , CsPbBr ₃	CsPb ₂ Br ₅ , Cs ₄ PbBr ₆ : hexagon CsPb ₂ Br ₅ : cubes CsPbBr ₃ : cubes	Cs ₄ PbBr ₆ : 30 nm CsPb ₂ Br ₅ : 10nm CsPbBr ₃ : 18 nm		oleic acid, oleylamine	30	2017	15
CsPbX ₃	nanowires	lateral: μm thickness: 5 layers (3nm)	orthorombic	oleyl ammonium, oleic acid	30	2017	16

Table S2. Summary of metal halide perovskite nanostructures synthesized by ligand-assisted hot-injection methods.

Chemical phase	Shape	Dimensions	Crystal structure	Capping agent	Injection Temperature (° C)	Date	Ref
CsPbX ₃	nanocubes	4-15 nm	cubic	oleic acid, oleylamine, of trioctylphosphine (CsPbCl ₃)	140-200	2015	17
CsPbX ₃	nanocubes	8 nm	cubic	oleic acid, oleylamine	170	2015	18
CsPbBr _{3-x} I _x 0 ≤ x ≤ 3	nanocubes	16 nm	Orthorhombic, cubic	oleic acid, oleylamine	160	2016	19
CsPbBr ₃ , CsPbBr _{1.6} I _{1.4}	nanocubes	9-11	cubic	poly(maleic anhydride-alt-1-octadecene), oleic acid, oleylamine	175	2016	20
CsSnX ₃ , X:Cl, Br, I CsSn(Cl _{0.5} Br _{0.5}) ₃	nanocubes	~10nm	CsSnCl ₃ : cubic, CsSnBr ₃ : orthorombic CsSnI ₃ : orthorombic	oleic acid, oleylamine	170	2016	21
CsPbX ₃	nanocubes, nanospheres	3-10 nm	cubic	oleic acid, octylamine	40-160	2016	22
CsPbI ₃	nanocubes	11-16 nm	Cubic	trioctylphosphine, oleic acid, oleylamine,	100-170 (depends on the desired size)	2017	23
CsPbBr ₃ -TiO ₂	Core: nanocube	Core:12 nm Core-shell:~	orthorhombic	Oleic acid, oleylamine	170 Calcination	2017	24

	bes Core- shell	20 nm			n of the CsPbBr ₃ / TiO _x composite at 300 °C for 5 h for the formation of the shell		
CsPbX ₃	nanopla telets nanoshe ets	nanoplatelets: lateral:~20 nm and thickness of ~3 nm nanosheets: few hundred nm	cubic	oleic acid, oleylamine	90-130	2015	²⁵
CsPbX ₃	nanopla telets: 30×40 nm nanoshe ets	Lateral: 100 nm- μm	CsPbBr ₃ : Orthorho mbic CsPbCl ₃ :te tragonal CsPbI ₃ : cubic	oleic acid, oleylamine	60-150	2016	²⁶
CsPbBr ₃	nanoshe ets	lateral: 280nm- 5μm thickness: 3 nm	orthorom bic	octanoic acid, octylamine, oleic acid, oleylamine	50-150	2016	²⁷
CsPbBr ₃	nanocu bes, nanopla telets,	nanocubes: 7- 13 nm nanoplatelets thickness: 2- 4.5 nm	orthorho mbic	carboxylic acids amines with variable carbon chain lengths	120-140	2016	²⁸
CsPbBr ₃	nanocu bes, nanopla telets	nanocubes:5. 5-11 nm nanoplatelets: 3-70 nm	orthorom bic	oleic acid, oleylamine	165-190	2016	²⁹
CsPbX ₃	cubes, platelets and rods	cubes: 4-15 nm nanoplatelets: 40 nm wires: 10-30 nm in diameter length 50 nm- μm	structural transform ation from cubic to orthorho mbic	oleic acid, oleylamine, triocylphosphin e (in the case of CsPbCl ₃)	170	2017	³⁰
CsPbX ₃	nanowir es	5 μm 9-12nm	orthorho mbic	oleic acid, oleylamine	150-250	2015	³¹
CsPbBr ₃	nanowir es	width: 10-2.8 nm	orthorho mbic	short acid (octanoic acid or hexanoic acid) together with alkyl amines (octylamine and oleylamine)	70-130	2016	³²
CsPbBr ₃	nanowir es	length: μm thickness:2.2 nm	orthorom bic or cubic	oleic acid, oleylamine	160	2016	³³
RbPbI ₃	nanowir es	diameter: 32 nm length: up to	orthorho mbic	oleic acid, oleylamine	150	2017	³⁴

		several tens of micrometers					
CsPbBr ₃	nanospheres nanoplatelets nanosheets	nanospheres: 2.4 nm nanoplatelets: 16×2.3 nanosheets: 75 nm	orthorhombic	oleic acid, oleylamine	90	2016	³⁵
Cs ₂ SnI ₆	Quasi-spherical	12-38 nm	-	No-organic ligand	80-220 (depends on the desire size)	2017	³⁶
Cs ₄ PbX ₆ (phase transformation in CsPbBr ₃ by the addition of PbBr ₂)	quite spherical	9-37 nm	hexagonal	oleic acid, oleylamine	80	2017	³⁷
CH ₃ NH ₃ PbBr ₃	spheres	4-6.5 nm	cubic	different amines	120	2015	³⁸
FA _{0.33} Cs _{0.67} PbBr _{3-x} I _x (0 ≤ x ≤ 3)	nanowires, nanosheets	nanowires: width: 15-300 nm length: several μm nanosheets: lateral: 2-4 μm thickness: 4.2 nm	orthorhombic	oleic acid, oleylamine, bis(2-ethylhexyl)-amine	160	2017	³⁹

Table 3. Summary of colloidal methods for the fabrication of perovskite oxide nanostructures.

Chemical phase	Precursors	Reaction or Calcination temperature	Shape	Dimensions (nm)	Crystal structure	Capping agent	Date	Ref
Sol-gel Method								
BaTiO ₃	barium and titanium methoxyethoxides	800-1300	randomly-shaped	20-100	cubic (tetragonal distortion)	free	1995	⁴⁰
BaTiO ₃	barium titanium ethyl hexanoisopropoxide	100	spherical, cubic	6-12	cubic	oleic acid	2001	⁴¹
BaTiO ₃	barium acetate, titanium isopropoxide	100-1000	spherical	40-250	cubic, tetragonal (1000° C)	free	2004	⁴²
BaTiO ₃	BaTi[OC ₂ H ₄ (C ₂ H ₅)OCH ₃] ₆	750-1000	quasi-spherical	6-32	cubic	free	2006	⁴³
BaTiO ₃	Barium carbonate, titanium alkoxide	400-1000	randomly-shaped	54	tetragonal	free	2009	⁴⁴
BaTiO ₃	Barium acetate, Titanium butoxide	900	randomly-shaped	55 (with hexanoic acid) 65 (with hexanedioic acid)	tetrahedron	hexanedioic and hexanoic acids	2009	⁴⁵
BaTiO ₃	barium acetate, tetrabutyl titanate	500-900	randomly shaped	25	cubic	free	2009	⁴⁶
BaTiO ₃	barium acetate, titanium tetraisopropyl alkoxide	600-900	randomly shaped	30	cubic	free	2011	⁴⁷

BaTiO ₃	barium acetate, titanium butoxide	600 900	randomly shaped	19.6 97.1	cubic tetragonal	free	2013	48
BaTiO ₃	barium acetate, titanium isopropoxide	-	randomly-shaped	60	tetragonal	free	2014	49
BaTiO ₃	barium acetate, titanium tetraisopropoxide	500-1100	randomly shaped	18-28	cubic (18-20 nm), tetragonal (24-28 nm)	disodium ethylenediaminetetraacetate	2016	50
PbTiO ₃	lead acetate, titanium (IV) isopropoxide	400-700	quasi spherical	3	cubic, monoclinic	free	2006	51
PbZr _x Ti _{1-x} O ₃	lead acetate, titanium (IV) ethoxide, and zirconium (IV) butoxide	700	spherical	10-30	tetragonal	tartrate	2001	52
Ba _x Sr _{1-x} TiO ₃	barium chloride, titanium tetraisopropoxide, strontium chloride hexahydrate	300-1000	quite spherical	20	-	free	2011	53
Tm ³⁺ (5%)-doped BaTiO ₃	barium acetate, titanium (IV) isopropoxide, thulium (III)	700	randomly shaped	20-30	cubic	free	2013	54

	oxide							
$BaTi_{1-x}Sc_xO_{3-\delta}$	barium acetate tetrabutyl titanium, scandium(III) acetate hydrate	300-800 (preheating) 1000-1400	randomly-shaped	30-40 300 (when $x=0.10$)	tetragonal, pseudo-cubic, hexagonal depends on T and x	free	2013	⁵⁵
$Ba(Ti_{1-x}Zr_x)O_3$, $0 \leq x \leq 0.2$	Barium nitrate, titanium (IV) isopropoxide, zirconium oxynitrate	700-1000	randomly-shaped	~20-50	cubic	free	2014	⁵⁶
$Ba_{1-x}La_xTiO_3$, $Ba_{1-x}La_xTi_{1-x/4}O_3$	barium isopropoxide, tetraisopropyl orthotitanate, lanthanum nitrate hexahydrate	900-1300	polyhedral particles	65	cubic (undoped: tetragonal)	free	2015	⁵⁷
$BaTi_{1-x}Fe_xO_3$	barium nitrate hexahydrate, tetrabutyl titanate, ferric nitrate nonahydrate	900	spherical	17-27	tetragonal (low Fe concentration), mixed phase tetragonal and hexagonal (high Fe concentration)	free	2016	⁵⁸
$[KNbO_3]_{1-x}[BaNi_{0.5}Nb_{0.5}O_{3-\delta}]_x$	barium ethoxide, potassium ethoxide, niobium Ethoxide	180	Quite spherical or cubic	15-20	orthorhombic, cubic depends on x	free	2016	⁵⁹

	e, Nickel 2-methoxyethoxide							
Ba _{0.5} Sr _{0.5} TiO ₃	barium acetate, titanium tetraoxide, strontium acetate, bismuth nitrate (III) pentahydrate	650-850	randomly shaped	35-40	cubic	free	2017	⁶⁰
Microwave Sol-gel								
BaTiO ₃ Ba _{0.95} La _{0.05} TiO ₃	barium acetate, titanium isopropoxide, lanthanum acetate and	700	nearly-spherical	700	tetragonal	free	2016	⁶¹
Hydrothermal methods								
BaTiO ₃	barium hydroxide octahydrate, titanium tetraoxide	150	randomly-shaped	10-90	cubic	free	1999	⁶²
BaTiO ₃	barium hydroxide, TiO ₂	80-240	randomly shaped	50-100	Mixture cubic tetragonal	free	2001	⁶³
BaTiO ₃ , SrTiO ₃	barium hydroxide (or Sr(OH) ₂), TiO ₂ particles	170	nanowires	diameter:50 lengths: μm	cubic	free	2005	⁶⁴
BaTiO ₃	barium	120-	nearly	50	cubic or	free	2008	⁶⁵

	chloride Dihydrate titanium tetrachloride	200	spherical		tetragonal depends on the T			
BaTiO ₃	barium hydroxide, Titanium dioxide sols	400	quite spherical	10-30	tetragonal	free	2008	⁶⁶
BaTiO ₃	barium hydrate, titanium (IV) <i>n</i> - butoxide	150- 250	randomly shaped	20-530	cubic	free	2009	⁶⁷
BaTiO ₃	barium nitrate titanium in the form of precipitated hydroxide (TOH),	200	dendritic	Diameter:10 0-150 Length 0.7- 1.5 μm	cubic	free	2009	⁶⁸
BaTiO ₃	titanium (IV) chloride solution , Barium nitrate	400	randomly shaped	6-13 90-260 (flocculated particles)	cubic	free	2010	⁶⁹
BaTiO ₃	barium nitrate, Titanium (IV) <i>n</i> - butoxide	135	cubes	22	pseudocubic	oleic acid	2010	⁷⁰
BaTiO ₃	barium hydrate, P25- TiO ₂ ,	100- 180	Spherical cubes	10–500 nm	cubic	free	2013	⁷¹
BaTiO ₃	Barium acetate, titanium (IV) isoprop	160- 250	cubes	40-80	tetragonal	free	2014	⁷²

	oxide							
BaTiO ₃	barium acetate, K ₂ Ti ₆ O ₁₃ (K2T6) nanowires	100-240	star-like and seaweed particles	width:~300 length: μm	mixture of cubic and tetragonal	free	2015	⁷³
BaTiO ₃	barium chloride dehydrate, titanium tetrachloride, and	150-230	torus-like and tetragonal	40-80	cubic or tetragonal depends on the T	polyvinylpyrrolidone	2017	⁷⁴
BaTi _{1-x} Fe _x O ₃	barium acetate, Titanium(IV) n-Butoxide, ferric nitrate nonahydrate	200	spherical	40-90	cubic	ethylenediamine	2008	⁷⁵
BaTiO ₃ , SrTiO ₃ , (Ba,Sr)TiO ₃	Barium nitrate, titanium(IV) n-butoxide, strontium nitrate	135	cubes	5-15	tetragonal	oleic acid oleylamine	2014	⁷⁶
BaTiO ₃ :Er ³⁺ and BaTiO ₃ :Yb ³⁺	barium chloride, titanium butoxide, erbium chloride and ytterbium chloride	180	randomly-shaped	5-10	cubic	free	2014	⁷⁷
Zn ₂ SnO ₄	zinc nitrate, tin chloride,	180	quite spherical	8		free	2012	⁷⁸

Sol-hydrothermal method								
BaTiO ₃	tetrachloride titanate, barium chloride	80-220	spherical	50	tetragonal	free	2010	⁷⁹
BaTiO ₃	barium hydroxide, octahydrate, tetrabutyl titanate	200	irregular-shaped, circular or rectangular-shaped depends on the alkalinity	10-200	cubic or tetragonal depends on the alkalinity	free	2013	⁸⁰
BaTiO ₃	tetrabutyl titanate, barium acetate	120-180	spherical	100-370	cubic	free	2013	⁸¹
BaTiO ₃	barium acetate, tetrabutyl titanate	200	hollow-like, ring-like, semicircle-like, spherical	30-90	mixture of tetragonal and cubic	free	2014	⁸²
BaTiO ₃	barium acetate, tetrabutyl titanate	100-120	quasi spherical or flattened	50	cubic	free	2016	⁸³
Ba _{1-x} Ti _{1-x} Gd _x S _c O ₃ (0 ≤ x ≤ 0.04)	barium acetate gadolinium (III), tetrabutyl titanium , acetate hydrate, scandium (III) acetate hydrate	180	randomly shaped	<100 nm	cubic	free	2015	⁸⁴
Dy-doped BaTiO ₃	barium acetate, tetrabutyl titanate, dysprosium(III) nitrate	200	quasi spherical	200-500	tetragonal	free	2016	⁸⁵

	hydrate								
$K_{1-x}Na_xNbO_3$	sodium acetate, potassium acetate, niobium ethoxide	180-220	nanowires, microfingers	diameter: 150 length: 4 μm	Orthorhombic (nanowires) rhombohedral-tetragonal (microfingers)	free	2016	⁸⁶	
Microwave Hydrothermal									
$BaTiO_3$	barium hydroxide octahydrate, barium nitrate, barium chloride, titanium (IV) n-butoxide	200	cubes	13	cubic or tetragonal	oleic acid	2016	⁸⁷	
Solvothermal									
$BaTiO_3$, $BaZrO_3$, $LiNbO_3$	titanium (iv) isopropoxide, zirconium (iv) isopropoxide isopropanol complex, niobium (v) ethoxide, barium metal, lithium metal	200-220	spherical ($BaTiO_3$) wormlike agglomerates ($BaZrO_3$)	$BaTiO_3$: 6 $BaZrO_3$: diameter: 2-3, length: 50	cubic or tetragonal	free	2004	⁸⁸	
$BaTiO_3$, $SrTiO_3$, $(Ba,Sr)TiO_3$	titanium (IV) isopropoxide, barium and strontium metal	200	quite-spherical	$BaTiO_3$: 4-5 $SrTiO_3$: 5-10 $Ba_{0.5}Sr_{0.5}TiO_3$: 5	Cubic or tetragonal	free	2004	⁸⁹	

BaTiO ₃	barium hydroxide octahydrate, titanium (IV) n-butoxide or titanium dioxide or metatitanic acid	180-200	quite spherical	25-500	cubic (25-50 nm) particles Mixture of cubic and tetragonal (80-500 nm particles)	cetyltrimethylammonium bromide	2010	⁹⁰
LiNbO ₃	LiNb(O-Et) ₆	235	Spherical, cubic	spheres: 40-60 cubes: 50-60	rhombohedral	free	2012	⁹¹
BaTiO ₃ , BaZrO ₃ , PbTiO ₃ , SrTiO ₃	barium nitrate, lead (II) nitrate	180	spheres, cubes	16-30 (spheres) 5-78 (cubes)	tetragonal distortion	oleic acid	2015	⁹²
LaNiO ₃	nickel (II) nitrate hexahydrate, Lanthanum (III) nitrate hexahydrate	180	hollow spherical	600-1000	rhombohedra	free	2017	⁹³
Sol-gel -solvothormal								
BaTiO ₃	barium acetate, tetrabutyl titanate	60-240	quite spherical	10-30	mixture cubic and tetragonal	free	2010	⁹⁴
Sonochemical method								
SrTiO ₃	strodium hydroxide, titanium isopropoxide	50	irregular-shaped	6-30	cubic	free	2003	⁹⁵
BaTiO ₃	barium chloride ,	80	spherical clusters	250	cubic	free	2010	⁹⁶

	titanium tetrachloride							
BiFeO ₃ , Bi _{0.9} Ba _{0.1} Fe _{0.9} Mn _{0.1} O ₃ , Bi _{0.9} Ca _{0.1} Fe 0.9Cr _{0.1} O ₃	barium nitrate, bismuth nitrate, ferric nitrate, manganese acetate, chromium nitrate	30	rods	diameter:20-50 length: 100-500	rhombohedral	free	2010	⁹⁷
BaTiO ₃	barium chloride, titanium tetrachloride	50-80	confetti-like clusters Polygons	70-600	cubic	free	2011	⁹⁸
XTiO ₃ ; Ba, Sr, Ni, Ba _{0.6} Sr _{0.4}	chloride salts (BaCl ₂ , SrCl ₂ , NiCl ₂), titanium chloride	50	quite-spherical	5-15	tetragonal	free	2015	⁹⁹
BaTiO ₃	barium hydroxide, diisopropoxytitanium bis(acetylacetonate)	25	bowl-like irregularly-shaped	55	cubic	free	2018	¹⁰⁰

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