Supporting Information

Progress of Surface-Modified Inorganic Phosphors for Performance Improvement: From Methods to Applications

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Table S1. Summary of the main control parameters of the preparation processes, including their differences in cost, scalability, precision, uniformity and thickness.

Preparation methods	Cost	Scalability	Precision	Uniformity (unevenness)	Thickness	Ref.
Sol-gel	Low	Medium	Medium (50-500 nm)	±3-20%	50 nm-200 μm	1
Spray drying	Medium	High	Low (0.5-5μm)	±5-30%	1-500 μm	2
Hot-injection	Low-Medium	Low-Medium	High (50 nm-1μm)	±2-15%	2-200 nm	3
Co-precipitation	Low	Industrial-grade	Low (Uncontrollable)	±10-40%	0.5-50 μm	4
CVD	High	High	High (10 nm-100s μm)	±2-15%	1 nm-100μm	5
ALD	high	Medium	Very high (0.1 nm)	±0.5-1%	0.1 nm-1 μm	6
Fluidized bed particle ALD	Very High	Medium	Very high (0.1 nm)	±3-5%	1-50 nm	7
Template	Medium-high	Low	High (Determined by the template)	±3-20%	5 nm-1 mm	8

Table S2. Summary of surface modification for rare-earth-doped downconversion phosphors

Categories	Coated	Method	Coating thickness	Test	λ_{ex} (nm)	λ_{em} (nm)	PLQY (%)	Application	Ref
$Ca_{0.8}Sr_{0.2}S:Eu^{2+}/Tm^{3+}$	SiO_2, TiO_2, Al_2O_3	Sol-gel	2-5%	XRD, SEM	~254	~620	-	-	9, 10
$ZnS:Ag^{+}/Cl^{-}$	SiO_2	-	130 nm	SEM,	325	~445	-	-	11
$Y_2O_2S:Eu^{3+}$	SiO_2	Sol-gel	10-20 nm	TEM, FTIR, ICP-AES, zeta potential	~254	~620	-	-	12
$ZnS:Ag^{+}/Cl^{-}/Al^{3+}$	SiO_2, Al_2O_3, MgO	Spray drying	15 nm	SEM, XPS	368, 410	450/520	-	-	13
$CaTiO_3:Eu^{3+}$	SiO_2	Sol-gel	5%	XRD, SEM	400	616	-	WLED	14
$YVO_4:Eu^{3+}$	SiO_2	Sol-gel	300-500 nm	XRD, FESEM, TEM	320	618	-	-	15
$BaMgAl_{10}O_{17}:Eu^{2+}$	MgO, carbon	Precipitation, CVD	-	SEM, TEM, HRTEM	254	450	60~70	-	16
$SrSe:Eu^{2+}$, $CaSe:Eu^{2+}$	MgO	Spray pyrolysis	5-10 wt%	FE-SEM, XRD, XPS	~254	565/608	-	WLED	17
$KBaBP_2O_8:Eu^{3+}$	ZnO:Al	Sol-gel	-	XRD, Zeta potential	394	594/620	-	WLED	18
$CaS:Eu^{2+}/Sm^{2+}$	SiO_2-PMMA	Sol-gel+ Dissolution-cohesion	10 wt.%	XRD, TEM, FTIR,	275	628	-	-	19
$CaS:Eu^{2+}/Cu^{+}$	CaZnOS, $CaZnOS:Mn^{2+}$, $CaZnOS:Pb^{2+}$	Solid-state	CaS:Eu:nZnO n>0.7	XRD, SEM, CL	530	650	68.78	Plant cultivation	20-22
$SrLiAl_3N_4:Eu^{2+}$	Organosilica	High-pressure solid-state reaction	400-600 nm	TEM, NMR	442	654	~49	WLED	23
$Sr_2Si_5N_8:Eu^{2+}$	TEOS, PDMS, Al_2O_3, $SrSi_2O_2N_2$	fluidized bed reactor ALD, deposition-precipitation	5-11 nm(Al2O3)	TEM, HRTEM, FTIR, SEM	467, 538	~611	64	WLED	24, 25
$Ba_2SiO_4:Eu^{2+}$	TEOS, PDMS	Sol-gel	-	SEM, FTIR, Contact angle	365	~525	66.84	WLED	26
β-SiAlON:Eu^{2+}	SiO_2	Sol-gel	TEOS:H2O=1:1	XRD, SEM	405	541	61	-	27
$Y_3Al_5O_{12}:Ce^{3+}$	Al_2O_3, SiO_2, ZnO	Coprecipitation, Wet chemical, ALD	0.16%, 25 nm, 5 nm	XRD, FTIR, TEM, SEM, XPS	460	~525	65	WLED	28, 29
$RbLi(Li_3SiO_4)_2:Eu^{2+}$	Al_2O_3@ODTMS	ALD	80 nm	SEM, TEM, XRD, FTIR, High-resolution XPS	365	530	87	WLED	30
$Y_2O_3:Eu^{3+}/Tb^{3+}$	g-C_3N_4	Vapor			305	543/613	88.2	-	31
$Y_2O_3:Eu^{3+}$	SiO_2	deposition	8 nm	XRD, SEM, TEM,	395	628	68	-	32

$Ba_3LaNb_3O_{12}:Sm^{3+}$	OA	Laser vaporization	~1.5 nm	FTIR, XPS HRTEM, HAADF-STEM, XRD	408	564/600/647/707	11.7	WLED	33
$CdSiO_3:Ce^{3+}$	OA	Solvothermal treatment	-	-	347	400	-	Anti-counterfeiting (LFP)	34
$NaMgF_3:Tb^{3+}$	$NaMgF_3$	Solution combustion route	-	XRD, FTIR, XPS, FE-SEM, TEM	297	488/548/584/621	-	Information Storage	35
$Mg_2InSbO_6:Eu^{3+}$	OA	Hydrothermal synthesis	~2 nm	TEM	395	612	42.01	WLED, LFP	36
$Sr_3(PO_4)_2:Eu^{2+}$	$Sr_9MgLi(PO_4)_7$	Solvothermal treatment	-	-	365	408/625	76.1	WLED	37
$SrAl_2O_4:Eu^{2+}/Dy^{3+}$	SiO_2-P(MMA-BA), NH_4HF_2, H_3PO_4, B_2O_3, SiO_2	In situ growth	-	TEM, XRD, HAADF-TEM	354	520	33.05	-	38, 39
$LaF_3:Pr^{3+}$	SiO_2	Liquid-phase, Rapid combustion, In situ emulsion polymerization	25%, -	XRD, SEM, FTIR, pH meter, HRTEM	442	486/468/521/580/601	-	-	40
$BaSi_2O_2N_2:Eu^{2+}$	Al_2O_3	Dicrucible fluorating	-	SEM	275	~500	40	WLED	41
$Ba_2GdSbO_6:Sm^{3+}$	OA	ALD	4-10 nm	SEM, TEM, XPS, TGA	406	675	63.12	WLED, LFP	42
$Ba_2LuSbO_6:Eu^{3+}$	OA	Solvothermal treatment	-	Contact angles	250	595	79.34	LFP	43
$GdF_3:Tb^{3+}/Sm^{3+}$	SiO_2	Solvothermal treatment	-	FTIR, XRD	274	544	-	-	44
$ZrO_2:Eu^{3+}$	ZrO_2	Uniaxial electrospinning +Subsequent fluorination	1.88 µm	XRD, SEM, FTIR	238	612	27.72	-	45

The abbreviation "LFP" defines as "Latent fingerprints"

Table S3. Summary of surface modification for Ln^{3+}-doped phosphors

Categories	Coated	Method	Coating thickness	λ_{ex} (nm)	λ_{em} (nm)	Application	Ref
$GdOF:Nd^{3+}/Yb^{3+}/Er^{3+}$	SiO_2	Template	30 nm	808	534/670	Temperature Sensor	46
$NaGdF_4:Yb^{3+}/Tm^{3+}$	$NaYF_4$	Co-precipitation	-	980	480/800	-	47, 48
$NaGdF_4:Yb^{3+}/Er^{3+}$	$NaYbF_4$, $NaGdF_4:Yb^{3+}/Nd^{3+}$	Successive layer-by-layer	~2 nm	808	545/525	Temperature Sensor	49
$NaGdF_4:Yb^{3+}/Er^{3+}/Nd^{3+}$	$NaGdF_4:Nd^{3+}$	Solvothermal	-	793	522/540/660	Bioimaging	50
$Na_3GaF_6:Ho^{3+}/Yb^{3+}$	SiO_2	Co-precipitation	3 nm	980	476/540	Food Pigment Detection	51
$Na_3HfF_7:Yb^{3+}/Er^{3+}$	$Na_3ZrF_7:Yb^{3+}/Er^{3+}$, $CaF_2:Yb^{3+}/Zr^{4+}$	Injection/modified high-temperature decomposition	-	980	650/545	-	52
$NaYF_4:Yb^{3+}/Ho^{3+}$	ScF_3, $NaLuF_4:Yb^{3+}/Nd^{3+}$	Hot-injection recipe	-	980, 808	543/650	-	53, 54
$NaYF_4:Yb^{3+}/Er^{3+}$	SiO_2	Sol-gel	-	980	516-565	Temperature Sensor	55, 56
$NaYF_4:Yb^{3+}/Er^{3+}$	$CsMnCl_3$	Hot-injection,	0.36 nm	980	516-565	Anti-counterfeiting	57
$NaYF_4:Yb^{3+}/Er^{3+}$	CDs, PDA	Sol-gel	-	980	516-565	Bioimaging	123
$NaYF_4:Yb^{3+}/Er^{3+}$	$NaGdF_4:Yb^{3+}/Nd^{3+}@NaGdF_4$	Seed-mediated growth	~3.0@5.1 nm	808	525/540/660	-	58
$NaYF_4:Yb^{3+}/Tm^{3+}$	$NaYF_4:Yb^{3+}, Nd^{3+}@TiO_2$, $NaYF_4: Yb^{3+}/Ce^{3+}@NMC$, Cs_4PbBr_6	Thermal decomposition, Solvothermal	25 nm, 15 nm	980/808	380, 295, 524	-	59, 60
$LiYF_4:Yb^{3+}/Tm^{3+}$	$LiYF_4:Nd^{3+}@Li_xTi_{1-x}O_2$	Thermal decomposition	-	808/980	346/361/452/483/646	-	61
$LiYF_4:Tm^{3+}$	$LiErF_4@LiYF_4$	Epitaxial growth	-	1710	1523/974/796	Bioimaging	62
$LiYbF_4:Tm^{3+}$	$LiYbF_4@LiYF_4$	Co-precipitation	-	975	1680	Bioimaging	63
$Bi_3O_4Br:Er^{3+}$	Bi_2O_{3-x}	Solvothermal-calcination tandem	-	980	525/543/671	Photocatalytic degradation	64
$K_3ZrF_7:Yb^{3+}/Er^{3+}$	OA	High-temperature coprecipitation	-	980	656	Biodegradation	65
$NaYF_4:Yb^{3+}/Er^{3+}/Mn^{4+}$	PDA-PEG	Solvothermal	7 nm(PDA)	980	525/540/655	Bioimaging Nanoprobes	66

Table S4. Summary of surface modification for transition metal-doped phosphors

Categories	Coated materials	λ_{ex} (nm)	λ_{em} (nm)	PLQY (%)	Applications	Ref.
$Gd_3Ga_5O_{12}$:Cr^{3+}/Nd^{3+}	MSNs	254	745	-	Bioimaging	67
ZnS:Mn^{2+}	SnO_2	356	585	-	-	68
K_2GeF_6:Mn^{4+}	Al_2O_3	460	633	94	-	69
K_2SiF_6:Mn^{4+}	alkyl phosphate[(M/E/I)OP(Zn/Al/Ti)], OA, K_2SiF_6, Al_2O_3, $Na_2S_2O_4$, H_2NbF_7	460	630	88.86	WLED	70, 71
K_2TiF_6:Mn^{4+}	ODTMS, OA@SiO_2, K_2TiF_6	462	630	82.5	WLED	72
$BaGeF_6$:Mn^{4+}	PPG@$NaGdF_4$:Dy^{3+}	470	635	-	WLED	73
Cs_2TiF_6 :Mn^{4+}	CTF	466	~630	-	WLED	74
CaZnOS:Mn^{2+}	OA	336	580	59.08	-	75
$MgGa_2O_4$:Cr^{3+}/Ni^{2+}	MSNs	420	710/1270	81.91	Mini-LEDs	76
$ZnGa_2O_4$:Cr^{3+}/Sn^{4+}	MSNs	405/560; 252	693/705	-	Bioimaging	77-79
$ZnGa_2O_4$:Cr^{3+}/Ni^{2+}	MSNs	410/532	1285	-	Bioimaging	80
$ZnGa_2O_4$:Cr^{3+}	$ZnGa_2O_4$, HAc, OX, ZnO, MSNs	800/850	700	-	Bioimaging	81, 82

Table S5. Summary of surface modification for co-doped phosphors

Categories	Coated layers	λ_{ex} (nm)	λ_{em} (nm)	Applications	Ref
$NaGdF_4:Yb^{3+}/Tm^{3+}$	$NaGdF_4:Tb^{3+}$	808	~980/1060	-	83
β-$NaErF_4:Ce^{3+}$	$@NaYbF_4@NaYF_4$	980	1525	Bioimaging	84
$NaGdF_4$:A (A = Eu^{3+}, Tb^{3+})	$NaGdF_4:Yb^{3+}@Tm^{3+}@NaGdF_4:Yb^{3+}/Nd^{3+}$	808	615/450/540	-	85
$NaGdF_4:Yb^{3+}/Ho^{3+}/Ce^{3+}$	$NaYF_4:Yb^{3+}/Nd^{3+}$, $NaGdF_4$	808/800	872/1060	Magnetic Resonance Imaging	86, 87
$CaS:Eu^{2+}$	$CaZnOS:Mn^{2+}$	295/530	615/650	-	20
$ZnGa_2O_4:Cr^{3+}$	$ZnGa_2O_4:Ln^{3+}$	550	695	Bioimaging	88
$Zn_{1.2}Ga_{1.6}Ge_{0.2}O_4:Cr^{3+}$, $Zn_3Ga_2Ge_2O_{10}:Eu^{2+}$	$ZnGa_2O_4$, Zn_2GeO_4	254	-	-	89

Note: Co-doping refers to the synergistic incorporation of ions into the host and surface coating to form a cooperative co-doping system.

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