Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

SUPPORTING INFORMATION

Pressure-Controlled Synthesis of High-Performance $SrLiAl_3N_4:Eu^{2+}$ Narrow-Band Red Phosphors

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EXPERIMENTAL METHODS

Reagents. Strontium nitride (Sr_3N_2, 99.5%) and europium nitride (EuN, 99.9%) were obtained from Materion. Aluminum nitride (AlN, 97%) was acquired from Tokuyama Corporation. Lithium nitride (Li_3N, 99%) was supplied by Kojundo Chemical Laboratory.

Synthesis of $SrLiAl_3N_4:Eu^{2+}$. Eu^{2+}-doped $SrLiAl_3N_4$ red phosphor was synthesized through a solid-state reaction. Stoichiometric amounts of Sr_3N_2, Li_3N, EuN, and AlN were carefully ground in a glove box (O_2 < 1 ppm, H_2O < 1 ppm). The well-mixed precursors were loaded into BN crucibles, which were subjected to hot isostatic pressing (HIP) and gas pressure sintering (GPS). The pressure was increased up to the set point by using a compressor. The furnace was heated to 1,000 °C under different pressure levels for 4 h. The furnace was cooled to room temperature, and the pressure was released to atmospheric pressure. Finally, the as-prepared samples were ground and kept in the glove box for characterization.

Characterization. The phase and purity of the as-prepared powder samples were examined by X-ray diffraction (XRD) analysis using a D2 PHASER diffractometer (Bruker) with CuKα radiation source (λ = 1.5418 Å). Fine structure data including lattice parameters and atom position were obtained by synchrotron X-ray diffraction analysis (λ = 0.774910 Å) of BL01C2 beamline with a Debye–Scherrer camera at the National Synchrotron Radiation Research Center (NSRRC), Taiwan. Rietveld refinement was conducted with Total Pattern Analysis Solutions (TOPAS) 4.2 software. Photoluminescence properties were analyzed by a 150 W Xe lamp and a Hamamatsu R928 photomultiplier tube equipped with a FluoroMax-3 spectrophotometer (HORIBA, Japan). Morphologies of the samples were examined by a scanning electron microscope (SEM, JSM-6700F). The ratio of Eu^{2+}/Eu^{3+} was examined by Eu L_3-edge of X-ray absorption near-edge structure spectroscopy in florescence mode at BL17 beamline in NSRRC, Taiwan. Internal quantum efficiency, absorption, and external quantum efficiency were determined using an absolute PL quantum yield spectrometer (QY C11347, Hamamatsu, Japan). The ratio of atomic composition was determined through ICP-AES analysis (Agilent 725-ES ICP-AES, USA).

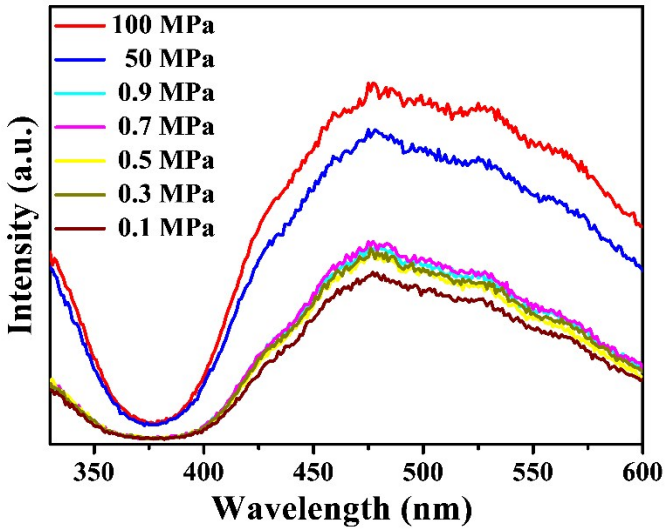

Figure S1. Photoluminescence excitation spectra of SLA synthesized under different gas pressure levels.

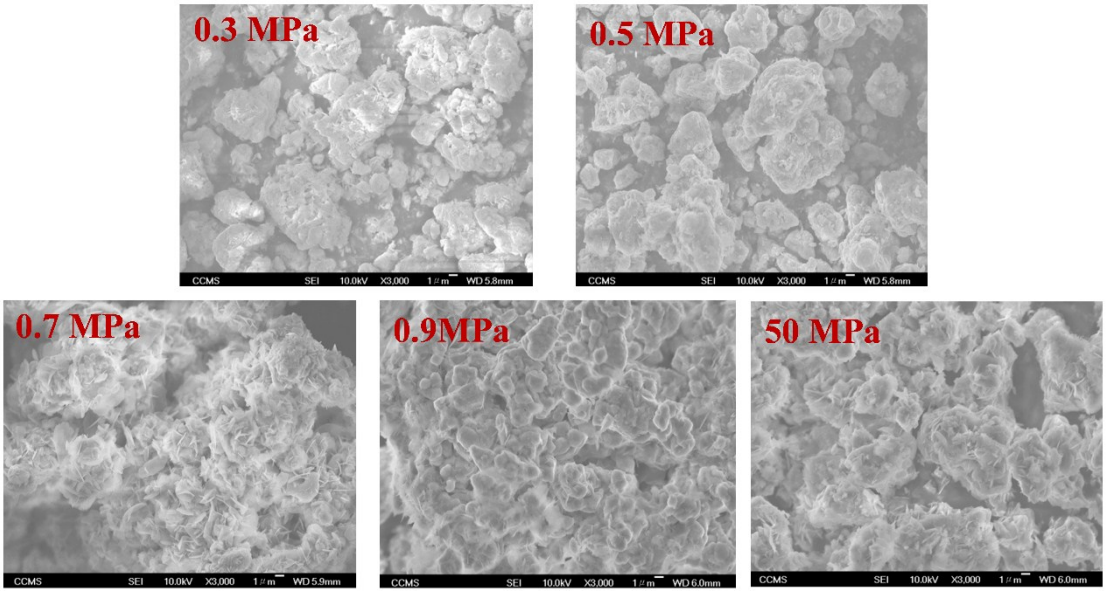

Figure S2. SEM images of SLA synthesized at 0.3, 0.5, 0.7, 0.9, and 50 MPa.

Table S1. Rietveld refinement results of sample fabricated at 0.1 MPa.

Space group	$P\bar{1}$
Cell Parameters	a = 5.8611(3) Å α = 83.602(2)° b = 7.4808(4) Å β = 76.758(2)° V = 416.07(4) Å^3 c = 9.9505(3) Å γ = 79.570(3)°
Reliability Factors	$\chi^2 = 1.89$ $R_{wp} = 7.94$ % $R_p = 5.77$ %

Atoms	x	y	z	Frac	Beq (Å^2)
Sr1	0.0019(21)	0.1334(17)	0.1286(12)	0.990(11)	1.0
Sr2	0.0186(17)	0.3810(17)	0.3715(12)	0.991(11)	1.0
Al1	0.5469(32)	0.9527(28)	0.1240(25)	0.953(39)	1.0
Al2	0.1818(32)	0.9518(29)	0.3991(25)	1.000(41)	1.0
Al3	0.1670(34)	0.7066(31)	0.1532(27)	1.000(36)	1.0
Al4	0.8247(30)	0.5563(29)	0.1035(24)	1.000(40)	1.0
Al5	0.4711(36)	0.5580(38)	0.3741(28)	1.000(31)	1.0
Al6	0.5645(35)	0.2044(37)	0.3665(29)	1.000(41)	1.0
N1	0.3657(91)	0.8568(78)	0.0183(61)	1.000(78)	1.0
N2	0.3729(98)	0.3408(87)	0.5234(57)	1.000(73)	1.0
N3	0.3703(95)	0.0883(82)	0.2677(64)	1.000(81)	1.0
N4	0.1556(81)	0.9425(74)	0.5917(59)	1.000(71)	1.0
N5	0.8437(80)	0.7921(75)	0.1431(63)	1.000(80)	1.0
N6	0.1906(77)	0.4968(70)	0.0779(57)	1.000(65)	1.0
N7	0.1773(79)	0.6962(69)	0.3484(61)	1.000(75)	1.0
N8	0.6538(73)	0.4091(67)	0.2286(56)	1.000(81)	1.0
Li1	0.444(20)	0.328(16)	0.127(14)	1.00(15)	1.0
Li2	0.201(19)	0.192(18)	0.647(16)	1.00(15)	1.0

Table S2. Rietveld refinement results of sample fabricated at 100 MPa.

Space group	$P\bar{1}$
Cell Parameters	a = 5.8620(4) Å α = 83.652(3)° b = 7.4770(4) Å β = 76.652(4)° V = 415.55 (4) Å^3 c = 9.9379(5) Å γ = 79.442(4)°
Reliability Factors	$\chi^2 = 2.15$ R_{wp} = 8.35 % R_p = 5.62 %

Atoms	x	y	z	Frac	Beq(Å^2)
Sr1	0.0079(27)	0.1317(22)	0.1280(16)	1.000(13)	1.0
Sr2	0.0148(24)	0.3773(24)	0.3715(16)	1.000(13)	1.0
Al1	0.5426(70)	0.9609(59)	0.1296(41)	1.000(52)	1.0
Al2	0.1779(61)	0.9407(63)	0.4007(49)	1.000(63)	1.0
Al3	0.1694(81)	0.7025(57)	0.1484(56)	0.992(45)	1.0
Al4	0.8148(68)	0.5552(64)	0.1108(47)	1.000(62)	1.0
Al5	0.4778(64)	0.5575(58)	0.3756(49)	1.000(42)	1.0
Al6	0.5746(54)	0.2018(57)	0.3693(44)	1.000(55)	1.0
N1	0.368(13)	0.859(13)	0.026(10)	1.00(12)	1.0
N2	0.348(13)	0.355(13)	0.520(10)	1.00(11)	1.0
N3	0.370(14)	0.091(12)	0.264(10)	1.00(12)	1.0
N4	0.150(12)	0.948(14)	0.5795(95)	1.000(97)	1.0
N5	0.864(11)	0.794(13)	0.154(10)	1.00(10)	1.0
N6	0.211(12)	0.458(12)	0.081(10)	1.00(10)	1.0
N7	0.199(11)	0.708(14)	0.3530(96)	1.000(96)	1.0
N8	0.634(15)	0.403(13)	0.236(10)	1.00(14)	1.0
Li1	0.457(25)	0.324(23)	0.121(21)	1.00(21)	1.0
Li2	0.182(23)	0.193(27)	0.643(23)	1.00(17)	1.0