Supporting information for publication

Transparent Ceramics Enabling High Luminous Flux and Efficacy for the Next-Generation High-Power LEDs Light

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Experimental

Materials and Synthesis. $Gd_{3-0.02}Al_4GaO_{12}$:0.02Ce^{3+} (GAGG:2%Ce^{3+}) TCs were fabricated by a solid state reaction and the procedure is illustrated in **Figure 1a**. The starting materials Gd_2O_3 (99.99%), Al_2O_3 (99.99%), Ga_2O_3 (99.99%), and $Ce_2(CO_3)_3$ (99.99%) were weighed in stoichiometric amounts, then mixed by ZrO_2 balls in ethanol for 12 h at a rotation speed of 300 rpm and dried at 65 °C for 24 h. The dried powder was calcined at 600 °C for 2 h and sieved through a 200-mesh screen, then pressed into a steel mold (Φ = 25 mm) to form pellets. The pellets were cold isostatically pressed under a pressure of 250 MPa to form green bodies. The specimens were sintered at temperatures of 1650 °C for 20 h in flowing oxygen atmosphere. After cooling down to room temperature, the samples were double-side polished to thicknesses of 0.4-1.0 mm for characterization.

Measurements and Characterization. Phase compositions of samples were analyzed by the X-ray diffraction (XRD) on a Bruker D8 Advance diffractometer with Cu Kα radiation with a scanning rate of 1°min^{-1} from 10 to 80°. Transmission measurements was obtained from 200 to 800 nm using a spectrophotometer (Lambda 950, Perkin Elmer Co., USA). Morphology was characterized using a field-emission scanning electron microscope (FE-SEM, Hitachi S-4800) equipped with an energy dispersive X-ray spectroscopy (EDS) system and a cathodoluminescence (CL) system (MonoCL4, Gatan). Particle size distribution of powders were obtained by wet dry laser particle size analyzer (S3500 - special, Microtrac, America). Specific surface area of powders was measured by specific surface area and porosity analyzer (ASAP2020M, Micromeritics Instrument Corporation, America). Photoluminescence excitation (PLE) and photoluminescence (PL) spectra were measured by a fluorescence spectrometer (F-4600, Hitachi, Tokyo, Japan). Hp-LED devices were fabricated in Sunpu-opto semiconductor Co. LTD. and measured by a spectroradiometer (HAAS2000, Everfine, China) under a driven current of 1 A. Fluorescence lifetimes of Ce^{3+} and temperature-dependent PL spectra were measured with a FL-311 Fluorescence Spectrometer.

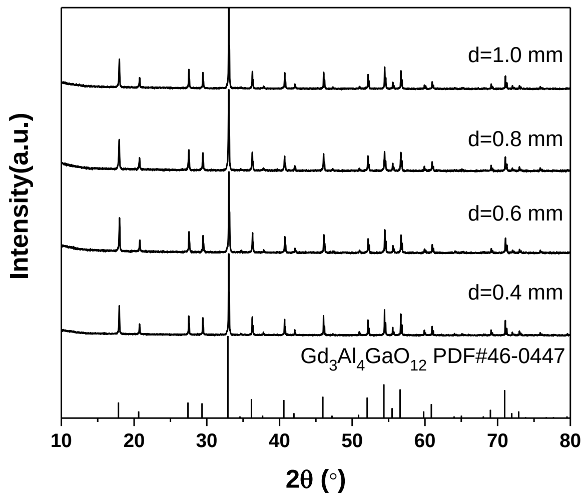

Figure S1 XRD patterns of GAGG:2%Ce^{3+} transparent ceramics with thicknesses of d = 0.4 - 1.0 mm.

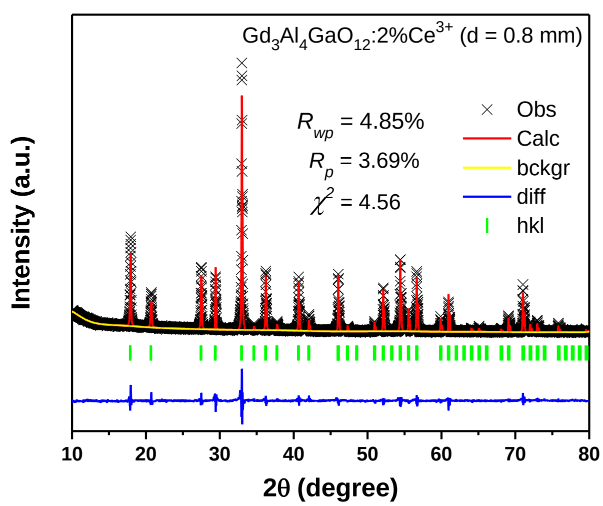

Figure S2 Representative experimental (crossed) and calculated (red solid line) XRD profiles of GAGG:2%Ce^{3+} for d = 0.8 mm.

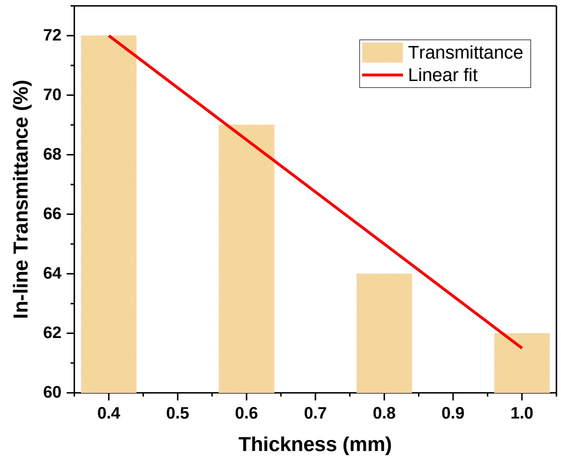

Figure S3 In-line transmittances of GAGG:2%Ce^{3+} transparent ceramics with thicknesses of *d* = 0.4 - 1.0 mm.

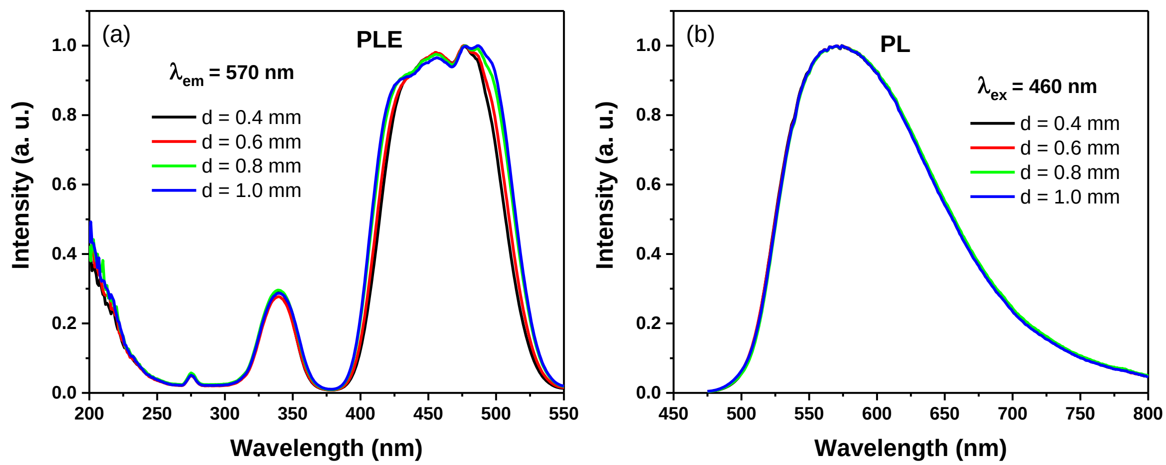

Figure S4 Normalized PLE (a) and PL (b) spectra of the GAGG:2%Ce^{3+} TCs with thicknesses of *d* = 0.4 – 1.0 mm.

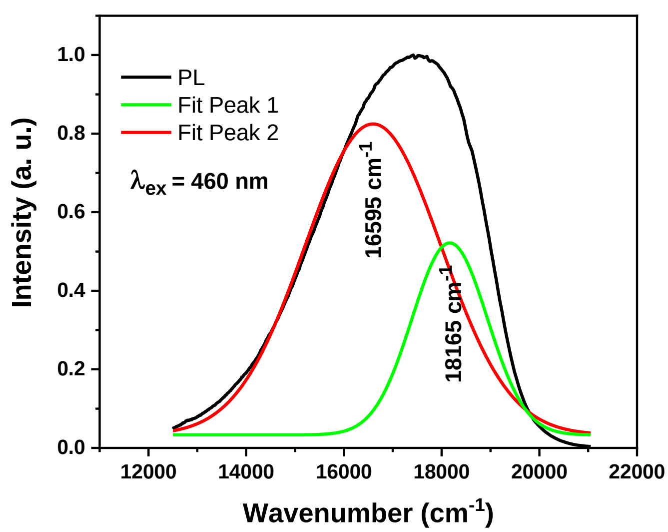

Figure S5 Gaussian fitting for the normalized PL spectrum of the GAGG:2%Ce^{3+} transparent ceramic with thicknesses of *d* = 0.8 mm.

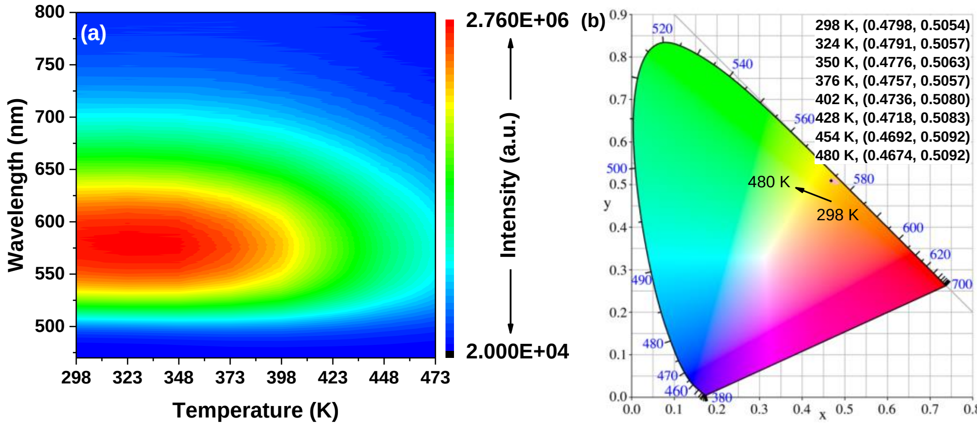

Figure S6 Temperature-dependent PL spectra (a) and CIE color coordinates (b) for the GAGG:2%Ce^{3+} transparent ceramic with thicknesses of *d* = 0.8 mm.

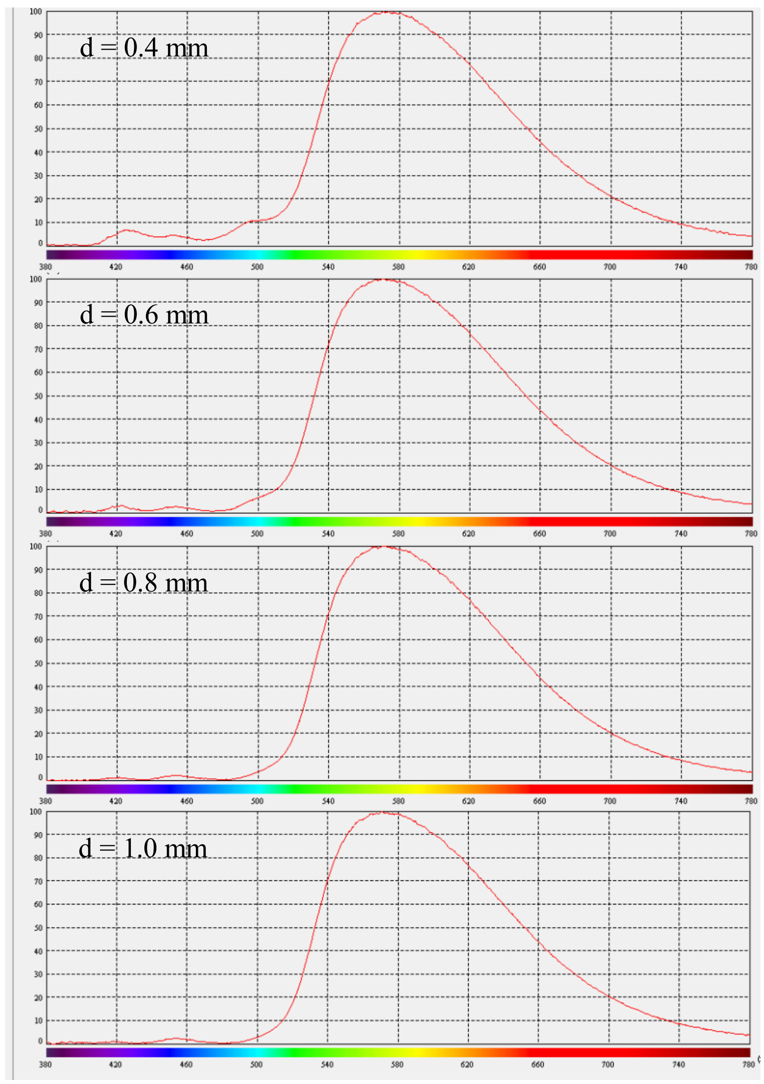

Figure S7 Electroluminescence spectra of GAGG:2%Ce^{3+} TCs (*d* = 0.4 - 1.0 mm) under 450 nm blue LEDs excitation.

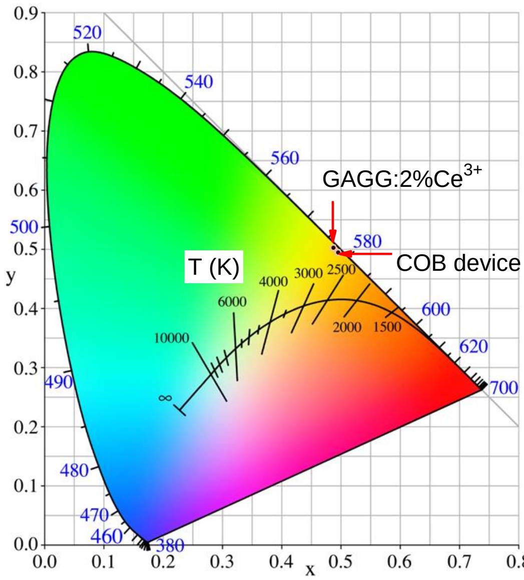

Figure S8 CIE color coordinates for the GAGG:2%Ce^{3+} transparent ceramic (d = 0.8 mm, (x, y) = (0.4881, 0.5029)) and the COB LED device ((x, y) = (0.4963, 0.4951)) using the same sample. Their color coordinates are close with each other demonstrating the light of the COB device is almost emissions of the GAGG:2%Ce^{3+} transparent ceramic.

Table S1. Performance results of GAGG:2%Ce^{3+} TCs (d = 0.4 – 1.0 mm) in hp-COB devices.

d (mm)	CCT (K)	Luminous flux (lm)	Luminous power (mW)	Luminous efficacy (lm/W)	CRI	x	y	Electric power (W)	Electric-luminous efficiency (lm/W)
0.4	2882	1643.24	4388.55	374.4	58.7	0.4845	0.4830	33.83	48.57
0.6	2859	1796.48	4667.43	384.9	56.1	0.4919	0.4939	34.03	52.79
0.8	2816	2098.26	5414.48	387.5	54.0	0.4963	0.4951	33.94	71.82
1.0	2794	1930.87	5006.90	385.6	54.3	0.4974	0.4936	33.82	57.09