

Electronic supplementary information

A two-step solid-state reaction to synthesize the yellow persistent $\text{Gd}_3\text{Al}_2\text{Ga}_3\text{O}_{12}:\text{Ce}^{3+}$ phosphor with an enhanced optical performance for AC-LEDs

Yong-Fu Liu,^{*a} Pu Liu,^{ab} Lei Wang,^b Cai-E Cui,^b Hao-Chuan Jiang^a and Jun Jiang^a

^a *Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, No. 1219 Western Zhongguan Road, Ningbo, 315201, P. R. China.*

E-mail: liuyongfu@nimte.ac.cn; Fax: +86-574-86382329; Tel: +86-574-87619207

^b *College of Physics and Optoelectronics, Taiyuan University of Technology, Taiyuan, 030024, P. R. China.*

Experimental

Samples with nominal composition of $\text{Gd}_{2.97}\text{Al}_2\text{Ga}_3\text{O}_{12}:0.03\text{Ce}^{3+}$ ($\text{GAGG}:3\%\text{Ce}^{3+}$) were prepared by using high purity oxides of Gd_2O_3 (5N), Al_2O_3 (4N), Ga_2O_3 (4N) and $\text{Ce}_2(\text{CO}_3)_3$ (4N) as starting materials. The reactants were thoroughly ground in an agate mortar for 1.5 h. The powder precursors were first sintered at temperature of 1400, 1500 and 1600 °C for 2 h in oxygen or air atmosphere. After cooling down to room temperature, the samples were ground again and then annealed in the CO reducing atmosphere at temperature of 1300, 1400, 1500 and 1600 °C for 2h. For comparison, a sample sintered directly in the CO reducing atmosphere at 1500 °C for 2h was prepared. X-ray diffraction (XRD) of the powder samples were measured on a Bruker D8 Advance diffractometer with Cu K α radiation. Photoluminescence (PL), photoluminescence excitation (PLE) and persistent decays were measured by a Hitachi F-4600 spectrometer. The IQE and external QE (EQE) were measured by a QE-2100 spectrophotometer from Otsuka Photol Electronics. The persistent photoluminescence (PPL) and persistent photoluminescence excitation (PPLE) spectra were recorded by a FL-311 spectrometer from Horiba Fluorolog.

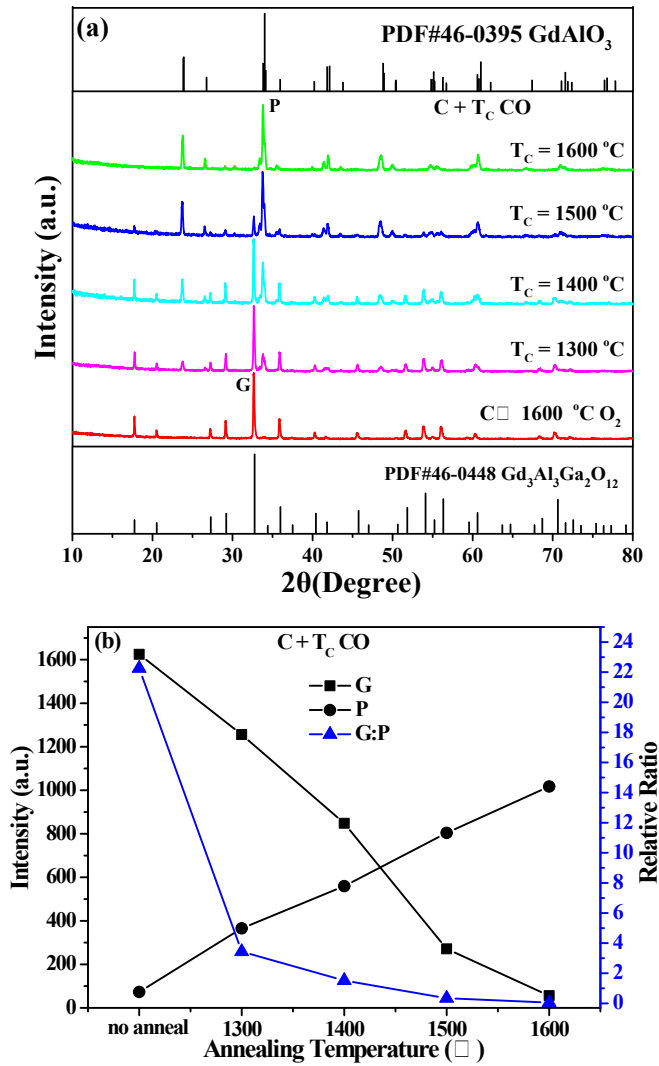


Fig. S1 XRD patterns (a) and diffraction peak intensities and ratios (b) of the garnet (G) and perovskite (P) phases of the $\text{GAGG}:\text{Ce}^{3+}$ sample sintered in O_2 atmosphere at 1600°C and then annealed in the CO reducing atmosphere at temperature from 1300 to 1600°C .

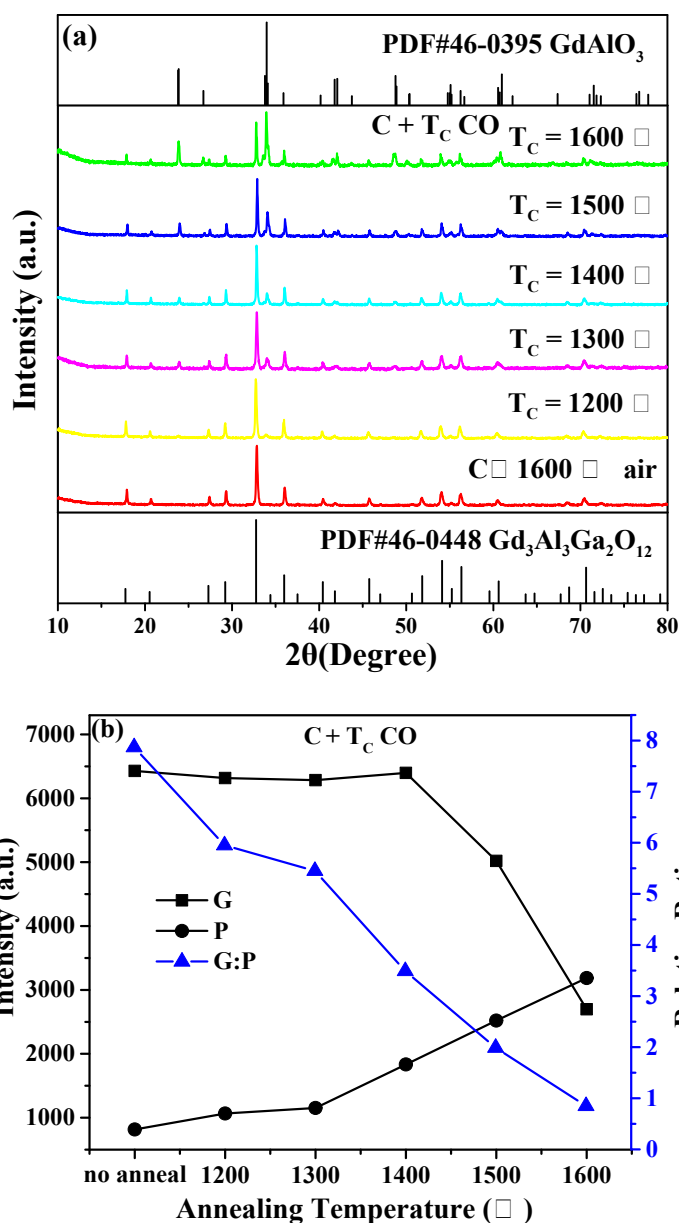


Fig. S2 XRD patterns (a) and diffraction peak intensities and ratios (b) of the garnet (G) and perovskite (P) phases of the $GAGG:Ce^{3+}$ sample sintered in air atmosphere at 1600 °C and then annealed in the CO reducing atmosphere at temperature from 1300 to 1600 °C.

Fig. S1 and S2 demonstrate that both O_2 and air atmosphere can guarantee the garnet phase formation of the $GAGG:Ce^{3+}$ persistent phosphor. Differently, P phase is obvious for the sample sintered in O_2 and annealed in CO as shown in Fig. S1. However, P phase is only obvious for the sample sintered in air and annealed in CO at high temperature. This is why the sample sintered in air and annealed in CO at proper temperature manifests high luminescence intensity.

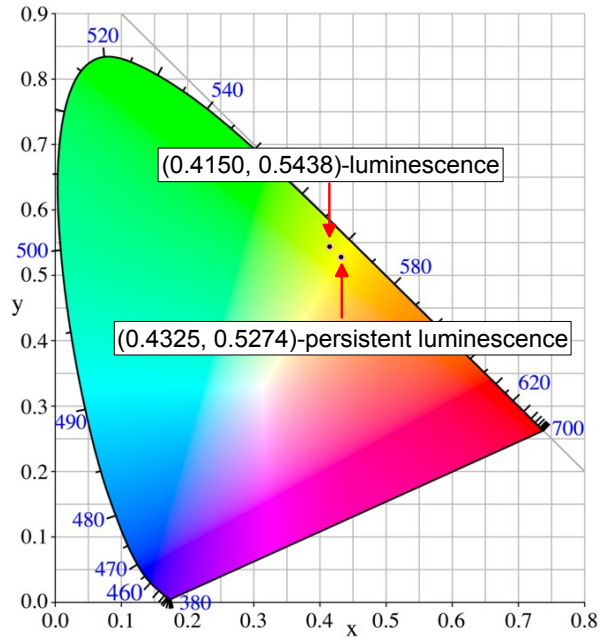


Fig. S3 CIE color coordinates for the luminescence in Fig. 2(a) and the persistent luminescence in Fig. 3(a) of the SACO62 sample.

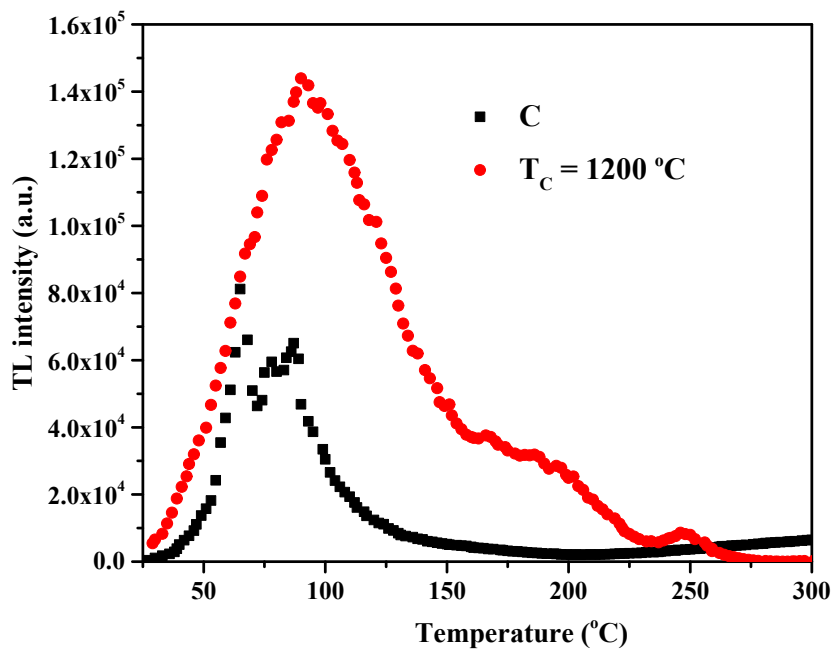


Fig. S4 Thermo-luminescence spectra for the sample only sintered in air (c) and the sample sintered in air and then annealed in CO at 1200 °C (T_C=1200 °C).

The thermo-luminescence spectra in Fig. S4 demonstrate the improved persistent luminescence of the GAGG:Ce³⁺ persistent phosphor is resulted from the increase of electron traps.