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Long persistent and photo-stimulated luminescence in Cr^{3+}-doped Zn-Ga-Sn-O phosphors for deep and reproducible tissue imaging

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Bio-imaging.

Bio-detection experiments were performed on anesthetized goldfish with chloral hydrate. SZG powders (0.1 g) dispersed in 10 mM PBS solution were injected into the fish belly. Injection depth is 5 mm under the epidermis. The SZG powders were excited 20 min with a Xenon (250 W) before injection. The long persistent luminescence images were acquired after the injection of 15 and 120 min, respectively. The photo-stimulated luminescence images were acquired excited by a 940 nm LED with the pump power 12 W for 1 and 15 min, respectively. Images are taken at the end of excitation. The photo-stimulated persistent luminescence images were acquired at 10 s after the NIR excitation. Before the measurements, the phosphors were pre-irradiated by a 940 nm LED for 1 min. The imaging was performed with a modified imaging system including Germany Pco Dicam Pro camera as the signal collector, and an external 940nm LED lamp as the excitation resource. Super-cold filters (Asahi, ZSC1100), long-pass filters (Asahi, ZVL630), and band-pass filters (Asahi, ZBPB147) were inserted to block the excitation light and transmit the emission light. Images were analyzed with home-made software.

Measurement of Absolute Quantum Yield.

The absolute photoluminescence quantum yields (QY) of SZG powder at room temperature were determined on an FLS920 spectrometer (Edinburgh, UK) with an integration sphere attachment. A 10 mm path length quartz cuvette for the solution sample is set in the integrating sphere. The absolute photoluminescence QY is given by:

$$QY = \frac{\int L_{Sample}}{\int E_{Reference} - \int E_{Sample}}$$

L_{Sample} is the photoluminescence intensity of the sample; $E_{Reference}$ and E_{Sample} are the excitation light intensities of the reference and the sample, respectively. The pure solvent (ultrapure water) was employed as reference.

Due to the transition overlap of Cr^{3+} [$^2E \rightarrow {}^4A_2$] and Cr^{3+} [$^4T_2 \rightarrow {}^4A_2$], the single QY could not be obtained respectively. The theoretical value should be smaller than the measured value. The QY of SZG powder is 82% (Figure s5), comparable to that of GZG powder (81%, Figure s6). Therefore, there is no difference in the QY of Cr^{3+} in two phosphors.

Figure Legend

Figure S1. XRD patterns of the sample SZG.

Figure S2. (a-b) Digital photos of GZG and SZG powders. (c) Afterglow spectra of SZG powder recorded at 2 min, 2 h and 24 h after the stoppage of irradiation. Before the measurements, the phosphor was pre-irradiated by a Xenon lamp for 5 min.

Figure S3. Effectiveness distinction of excitation wavelength, afterglow intensity of GZG and SZG powders monitored at 696 nm as a function of time after irradiated by 320, 410, 560 nm light for 5 min.

Figure S4. Bio-imaging in goldfish, (a) Without the injection of SZG powders, (b-c) Long persistent luminescence bio-imaging after the injection of 15 and 120 min, respectively.(d-e) Photo-stimulated luminescence bio-imaging excited by a 940 nm LED with the pump power 12 W for 1 and 15 min, respectively. Images are taken at the end of excitation. (f) Photo-stimulated persistent luminescence bio-imaging at 10 s after the NIR excitation, before the measurement, the phosphor was pre-irradiated by a 940 nm LED for 1 min.

Figure S5. The absolute photoluminescence quantum yield (QY) of SZG powder. The excitation wavelength is 408 nm, and the emission band is from 600 nm to 800 nm.

Figure S6. The absolute photoluminescence quantum yield (QY) of GZG powder. The excitation wavelength is 415 nm, and the emission band is from 600 nm to 800 nm.

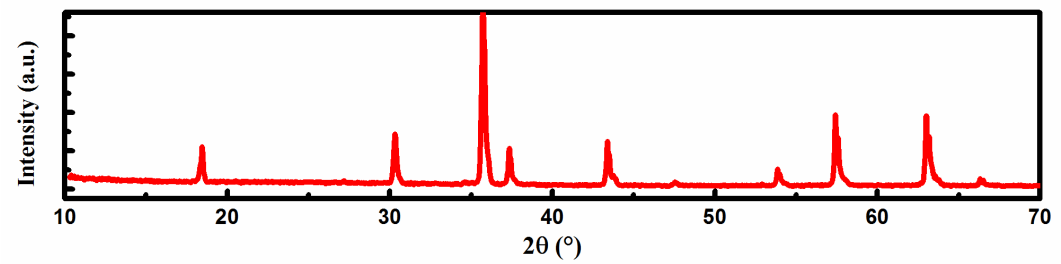

Figure S1


(a)
(b)
(c)
2min
2h
24h
Intensity (a.u.)
600
650
700
750
800
Wavelength (nm)

Figure S2

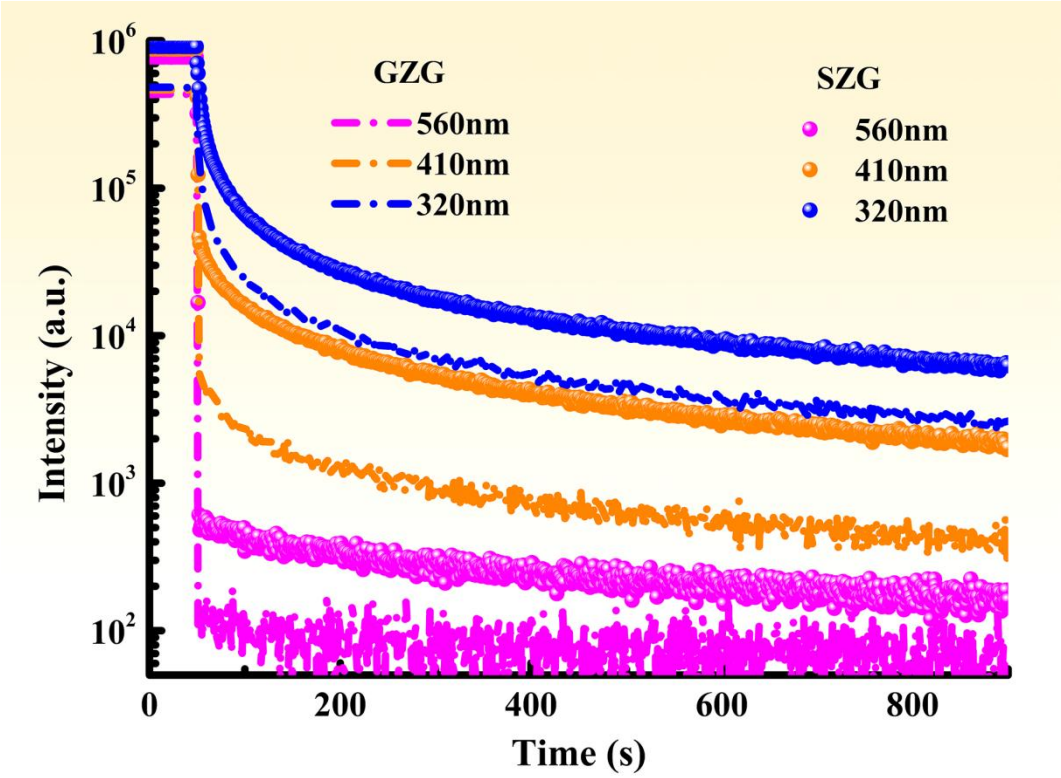
GZG
560nm
410nm
320nm
SZG
560nm
410nm
320nm
Intensity (a.u.)
10^6
10^5
10^4
10^3
10^2
0
200
400
600
800
Time (s)

Figure S3

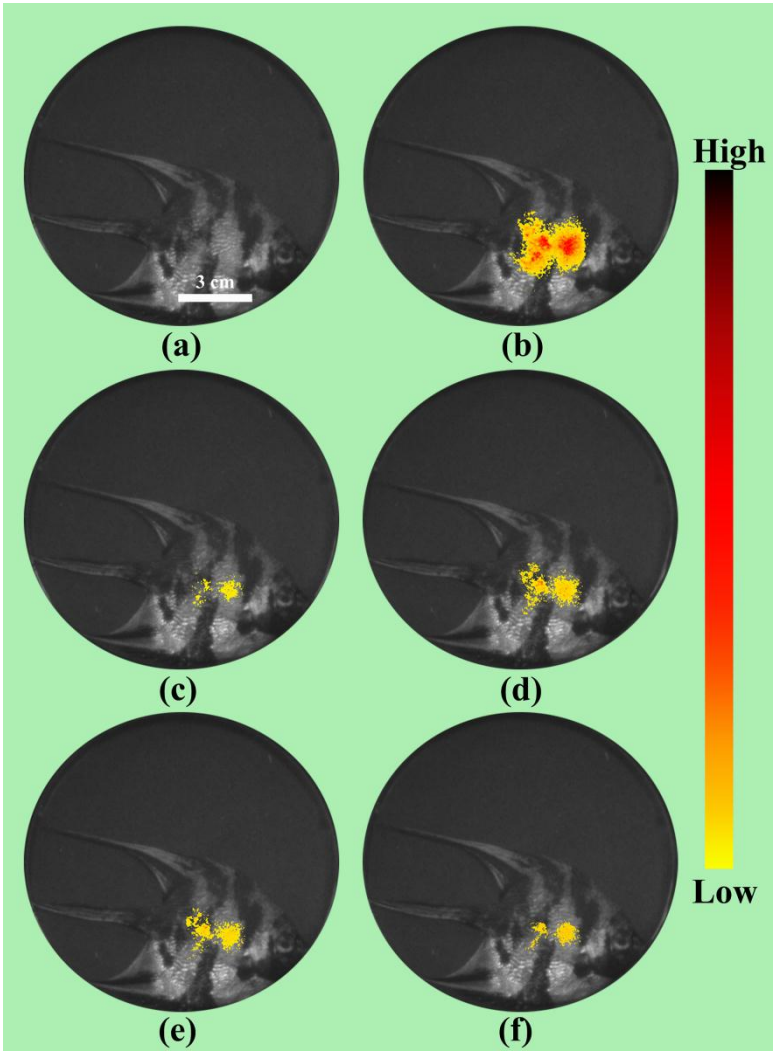

Figure S4

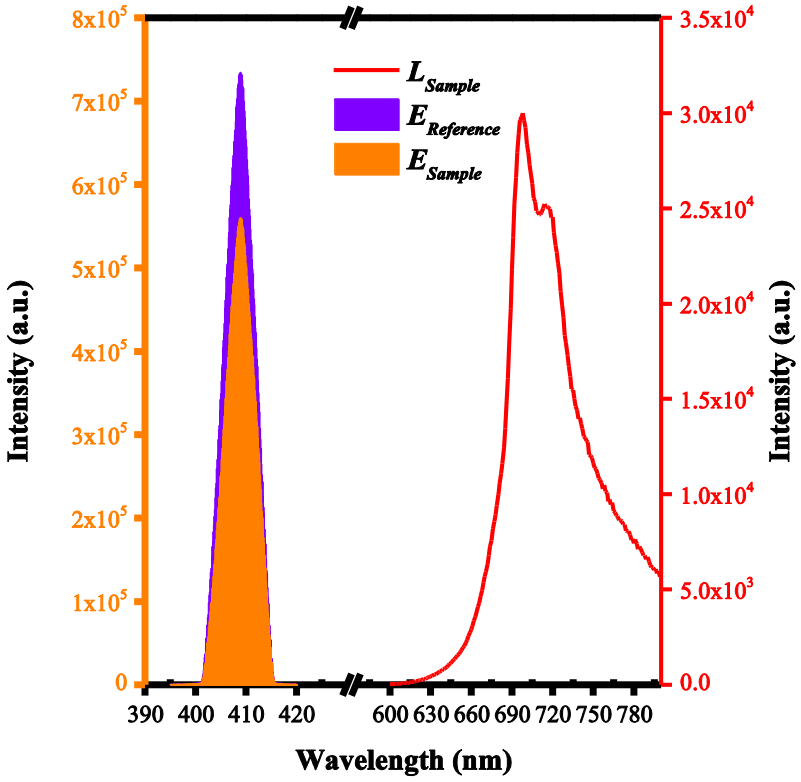
8x10^5
7x10^5
6x10^5
5x10^5
4x10^5
3x10^5
2x10^5
1x10^5
0
Intensity (a.u.)
3.5x10^4
3.0x10^4
2.5x10^4
2.0x10^4
1.5x10^4
1.0x10^4
5.0x10^3
0.0
Intensity (a.u.)
L Sample
E Reference
E Sample
390 400 410 420
600 630 660 690 720 750 780
Wavelength (nm)

Figure S5

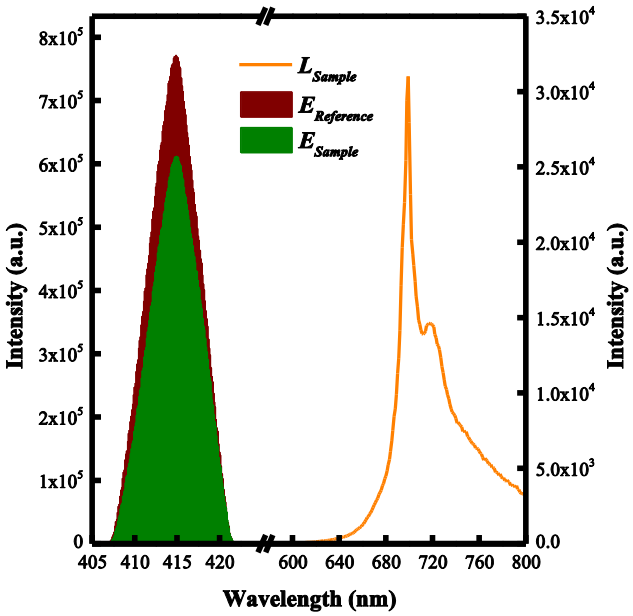
8x10^5
7x10^5
6x10^5
5x10^5
4x10^5
3x10^5
2x10^5
1x10^5
0
Intensity (a.u.)
3.5x10^4
3.0x10^4
2.5x10^4
2.0x10^4
1.5x10^4
1.0x10^4
5.0x10^3
0.0
Intensity (a.u.)
L Sample
E Reference
E Sample
405 410 415 420
600 640 680 720 760 800
Wavelength (nm)

Figure S6