Electronic Supplementary Information for

Hydrothermal and biomineralization synthesis of a dual-modal nanoprobe for targeted near-infared persistent luminescence and magnetic resonance imaging

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Chemicals and materials

$Zn(NO_3)_2·6H_2O$ (99%), Ga_2O_3 (99.99%), $Cr(NO_3)_3·9H_2O$ (99.99%), $Gd(NO_3)_3·6H_2O$ (99.99%), (3-aminopropyl)triethoxysilane (APTES, 99%), N-hydroxysuccinimide (NHS, 98%) and N-(3-Dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride (EDC·HCl, 98%) were obtained from Aladdin (Shanghai, China). Hyaluronic Acid (HA, Mw: 8290) was bought from Bloomage Freda Biopharm Co., Ltd. (Shangdong, China). N,N-Dimethylformamide (DMF) was obtained from Tianjin Concord Technology Co. Ltd. (Tianjin, China). All reagents were used as received without further purification. Ultrapure water (Hangzhou Wahaha Group Co. Ltd., Hangzhou, China) was used throughout the experiment.

Instrumentation

The X-ray diffraction (XRD) patterns were recorded on a D/max-2500 diffractometer (Rigaku, Japan) with Cu Kα radiation (λ=1.5418 Å). Transmission electron microscopy (TEM) and high-resolution TEM (HRTEM) images were acquired on a Philips Tecnai G2 F20 microscope (Philips, Eindhoven, Netherlands) at an acceleration voltage of 200 kV. The phosphorescence spectra and PL spectra were measured on an F-4500 spectrofluorometer (Hitachi, Japan). Fourier transform infrared spectra (FT-IR) spectra were recorded on a Nicolet 6700 spectrometer (Thermo Fisher Scientific, USA) with KBr as the background. Thermogravimetric analysis (TGA) data was obtained on a PTC-10A TG-DTA thermoanalyzer (Rigaku, Japan). Dynamic light scattering

(DLS) and zeta potential measurement were conducted on a Malvern Zetasizer (Nano series ZS, Worcestershire, UK). The Gd in the multimodal probe was determined on an Agilent 7700X ICP-MS (Agilent, USA). The NIR PL images were obtained on a Berthold NightOWL LB 983 Imaging System (Bad Wildbad, Germany) equipped with CCD camera (detection wavelength: 515-875 nm) under luminescence imaging mode without any excitation/emission filters. A HT/MRSI60-60KY 1.2T MRI system (Huantong Co. Ltd., Shanghai, China) was used for MRI. The imaging parameters were as follows: spin-echo MRI sequence, TR/TE = 100.0/8.8 ms, FOV = 100 × 50 mm^2, matrix = 256 × 256, slice thickness = 1 mm, 30.0 °C.

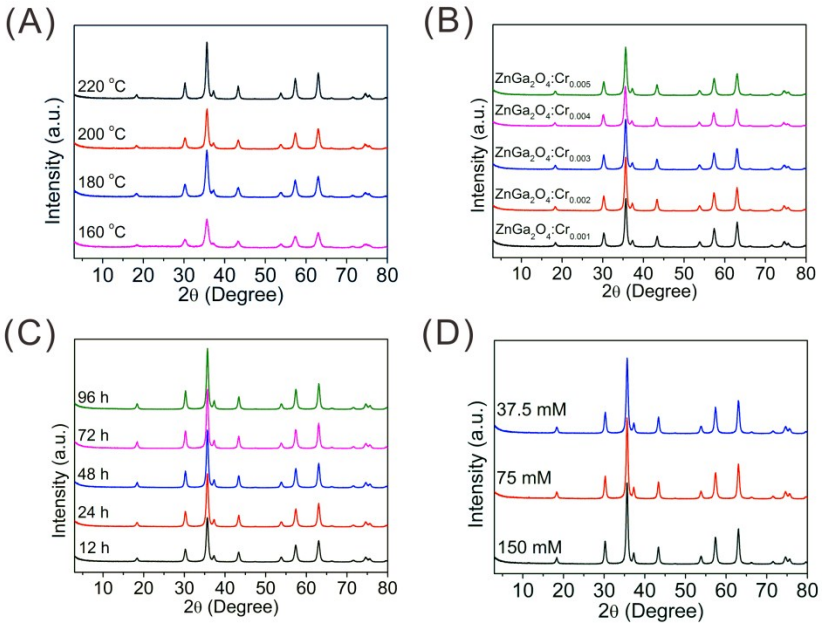

Fig. S1 Effects of synthesis conditions on the XRD patterns of the prepared PLNPs: (A) Reaction temperature; (B) Cr content; (C) Reaction time; (D) Reactant concentration.

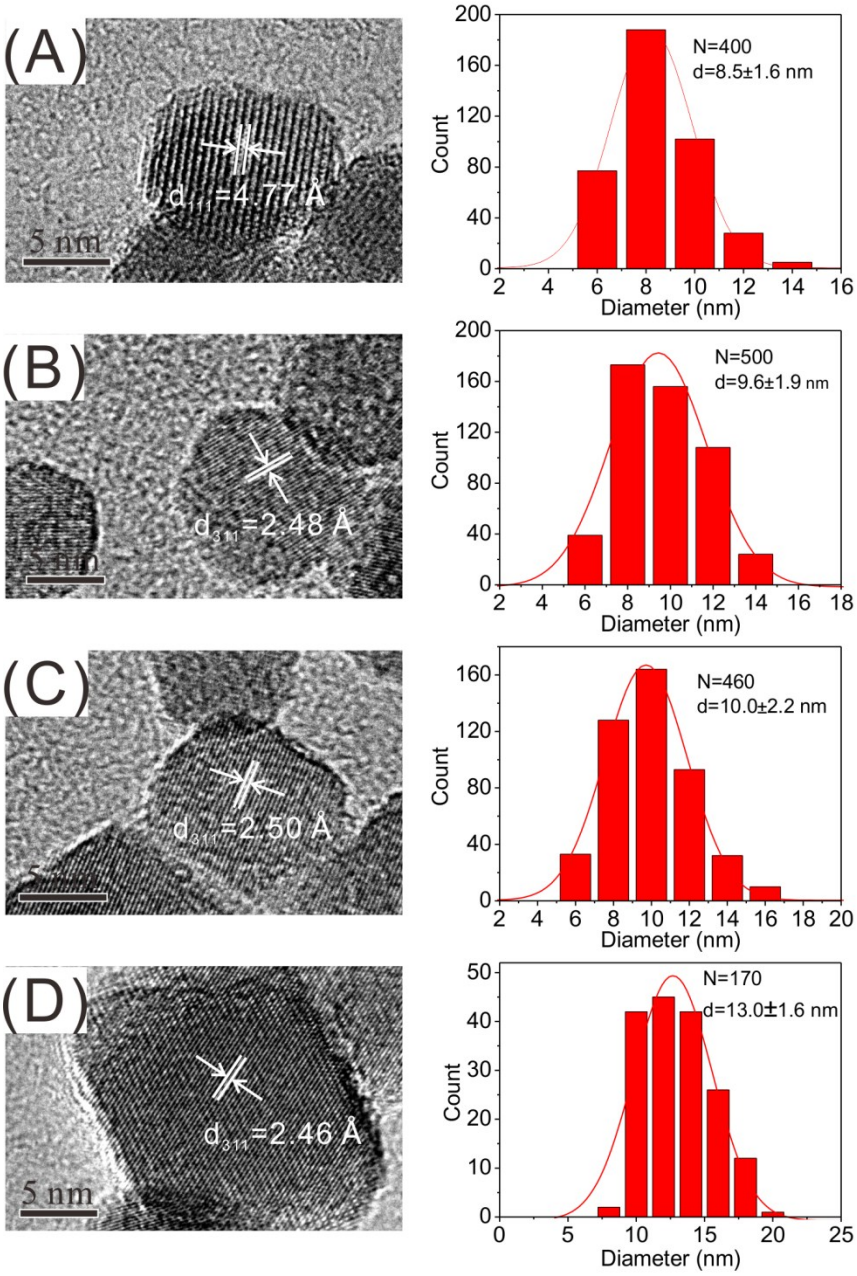

Fig. S2 HRTEM images (left) and size distribution (right) of the as-synthesized PLNPs at various temperatures: (A) 160 °C; (B) 180 °C; (C) 200 °C; (D) 220 °C.

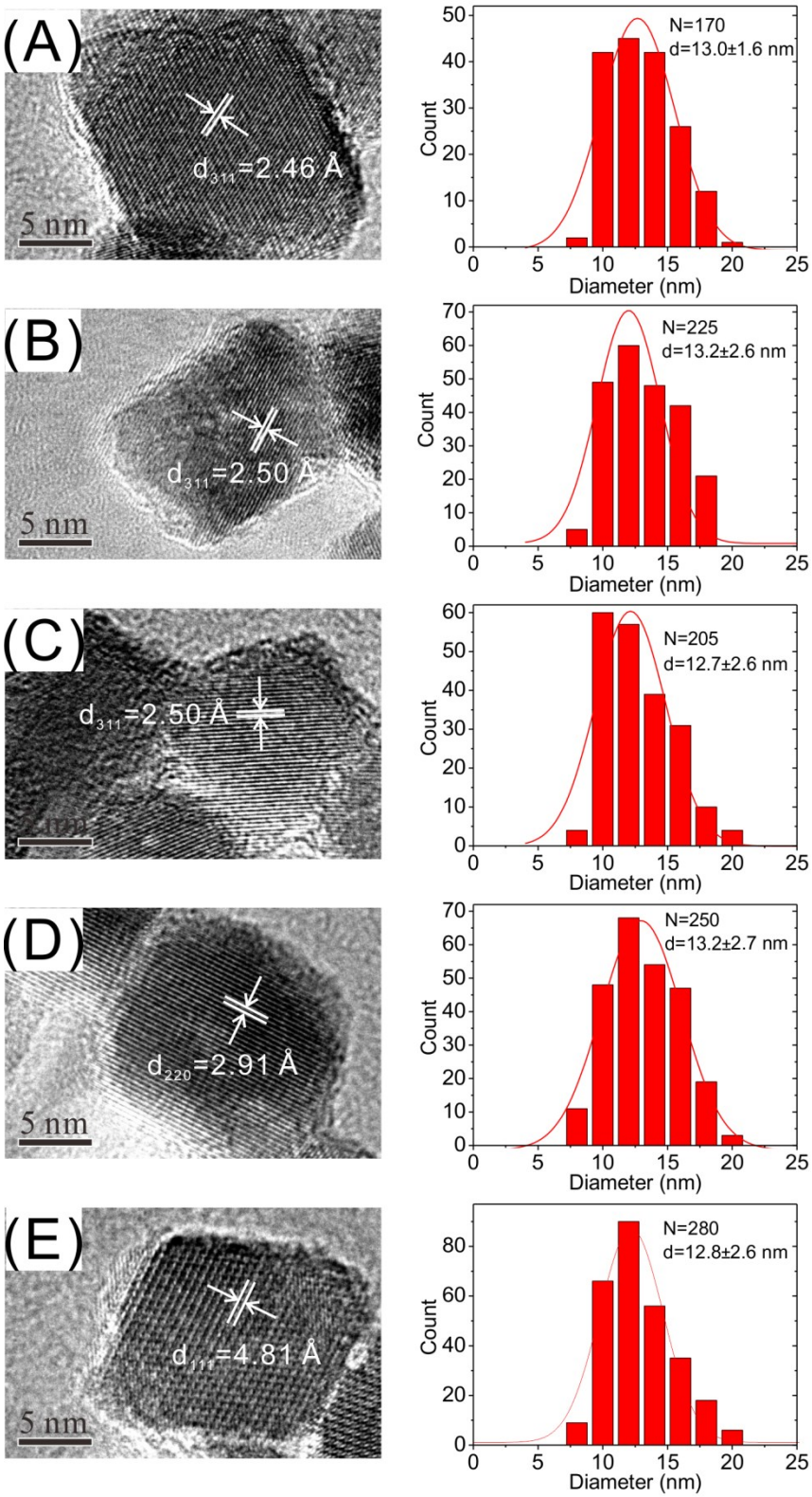

Fig. S3 HRTEM images (left) and size distribution (right) of the prepared PLNPs with different Cr contents: (A) 0.1%; (B) 0.2%; (C) 0.3%; (D) 0.4%; (E) 0.5%.

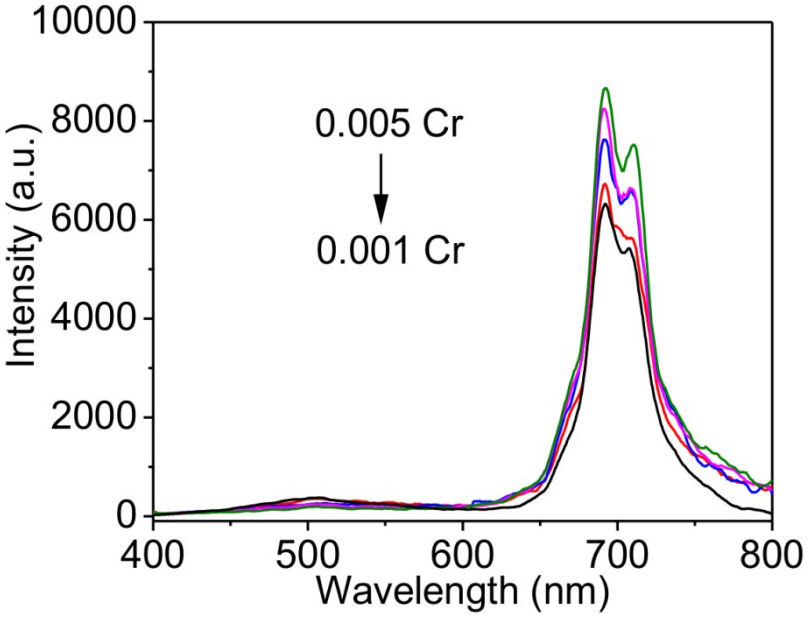

Fig. S4 Phosphorescence spectra of the PLNPs with different doping content of Cr.

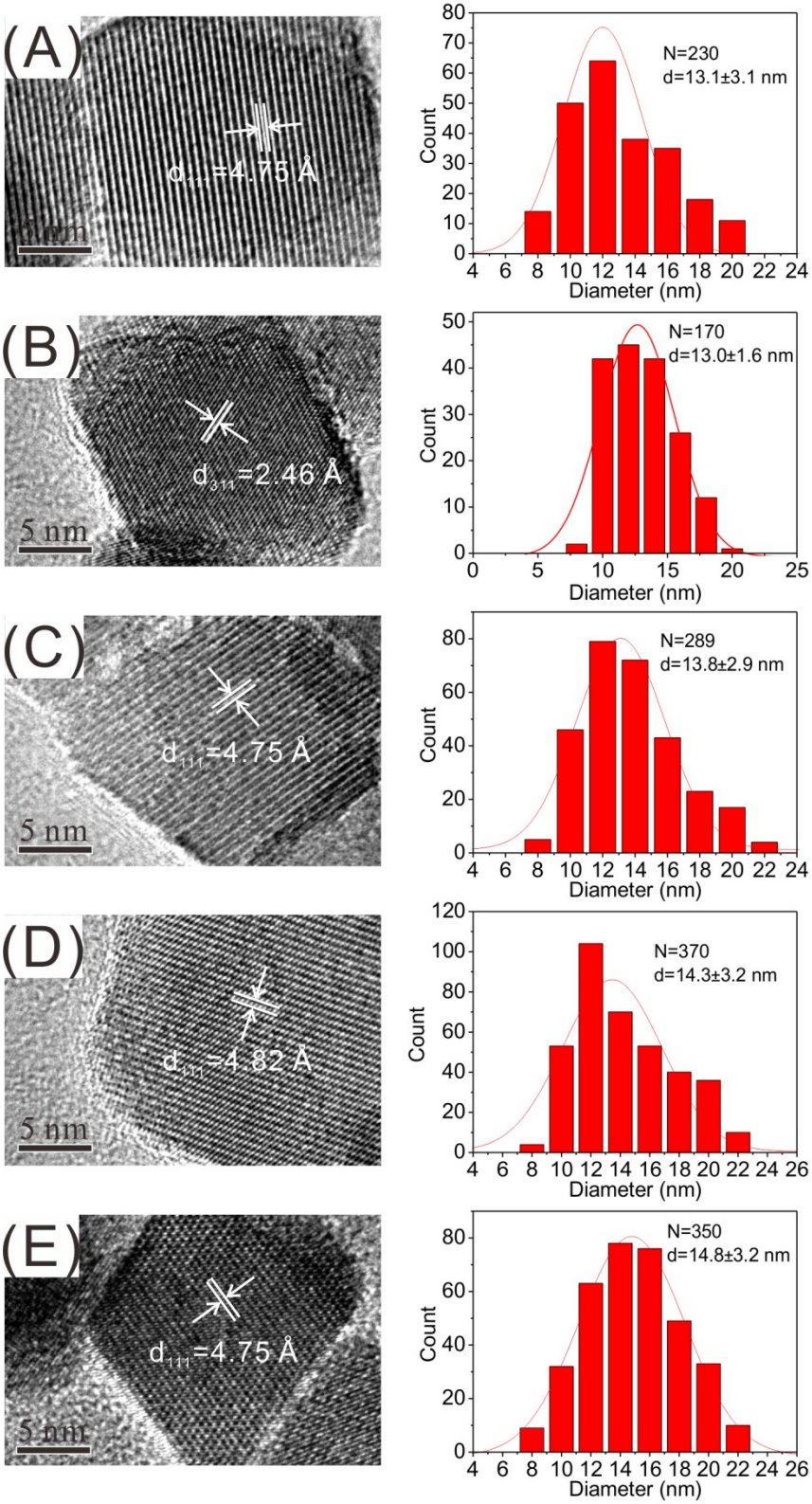

Fig. S5 HRTEM images (left) and size distribution (right) of the PLNPs synthesized with different reaction time: (A)12 h; (B) 24 h; (C) 48 h; (D) 72 h; (E) 96 h.

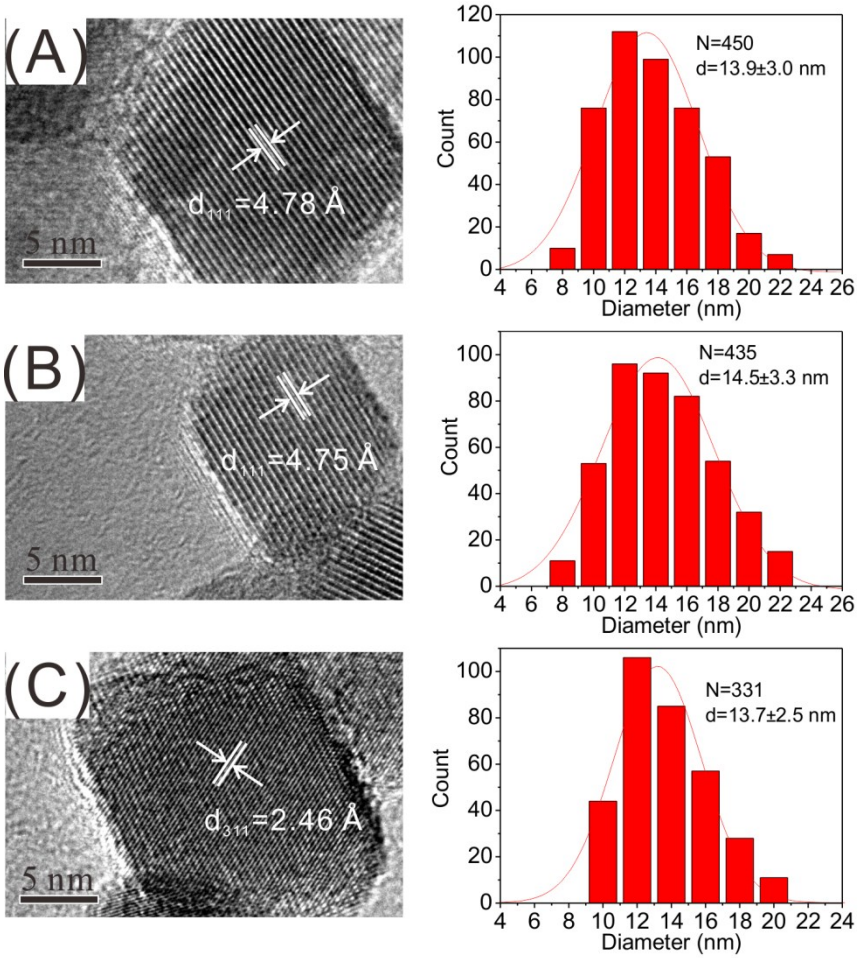

Fig. S6 HRTEM images (left) and size distribution (right) of the PLNPs synthesized with different reactant concentrations: (A) 37.5 mM; (B) 75 mM; (C) 150 mM.

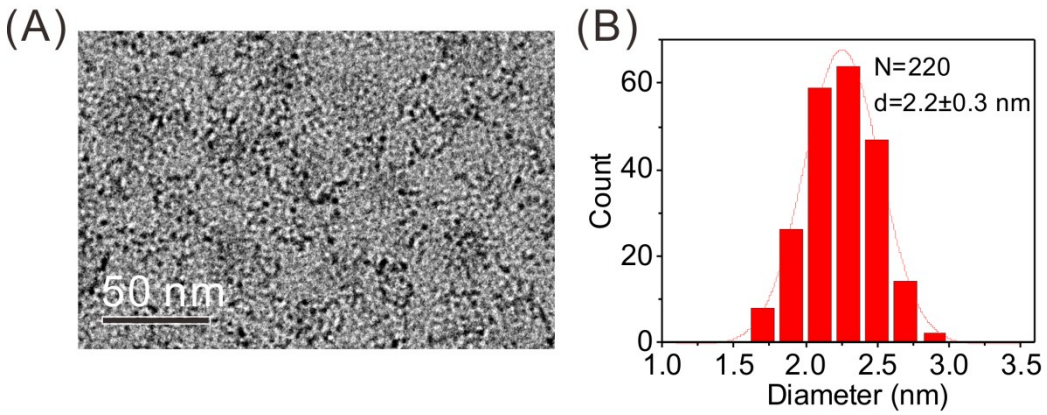

Fig. S7 (A) HRTEM image of HA-Gd_2O_3. (B) Size distribution of HA-Gd_2O_3.

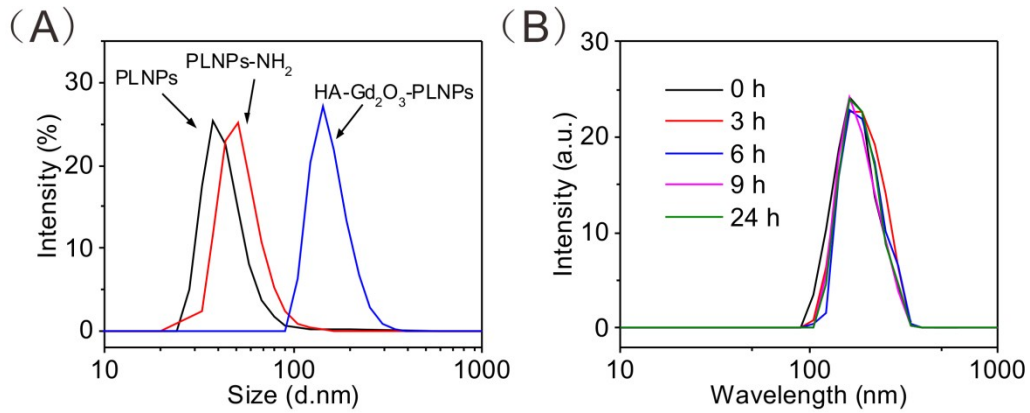

Fig. S8 (A) Dynamic light scattering spectra of the PLNPs, PLNPs-NH_2 and HA-Gd_2O_3-PLNPs in aqueous solution. (B) Dynamic light scattering spectra of the HA-Gd_2O_3-PLNPs in cell culture solution for 24 h.

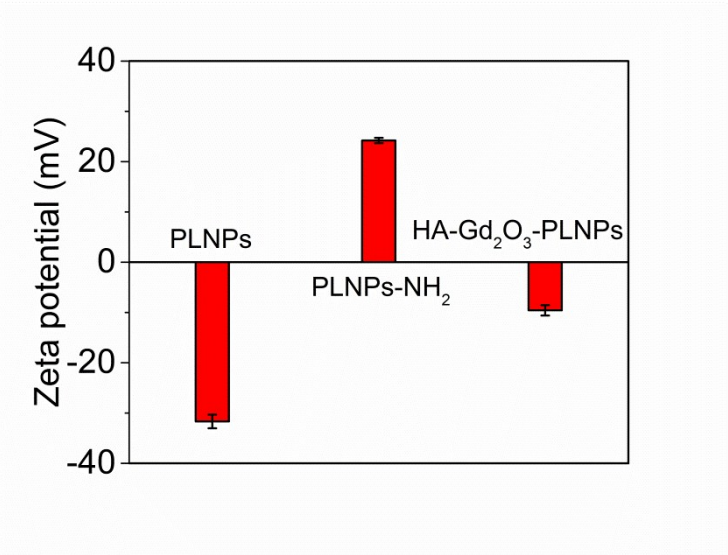

Fig. S9 Zeta potential of the PLNPs, PLNPs-NH_2 and HA-Gd_2O_3-PLNPs at PBS (pH=7.4).

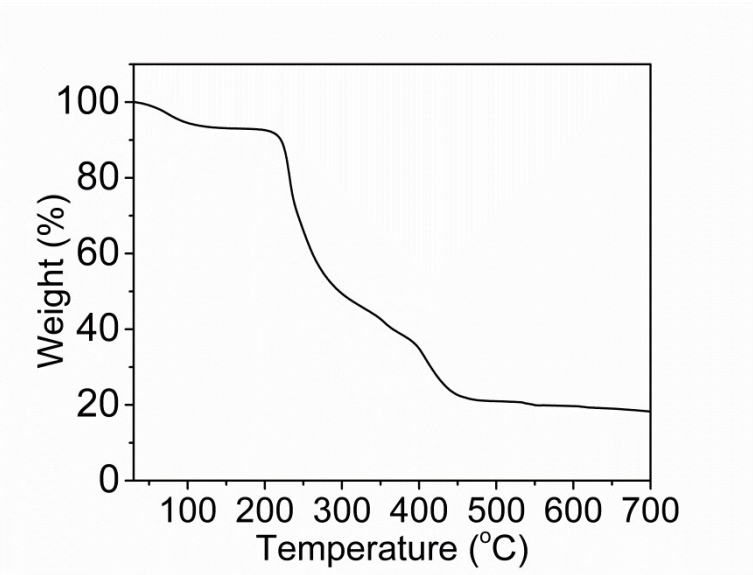

Fig. S10 TGA curve of HA.

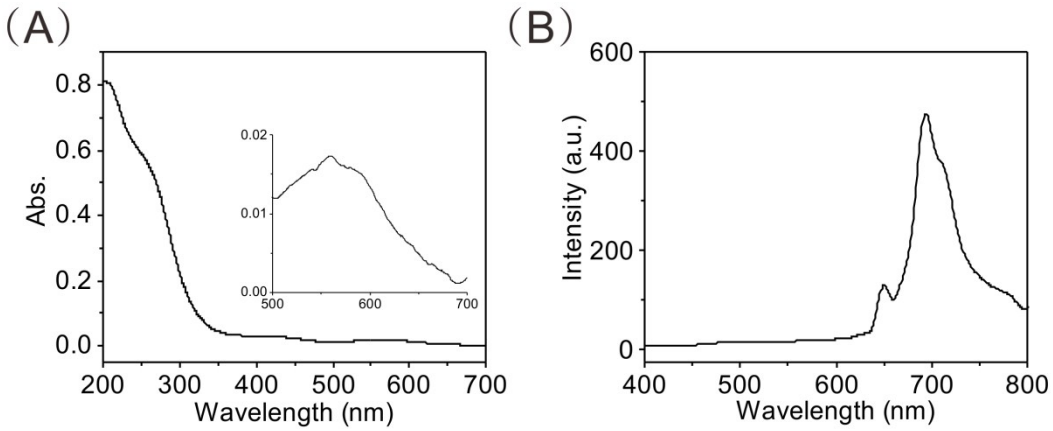

Fig. S11 (A) The UV-Vis absorption spectrum of the PLNPs. (B) Emission spectrum of the PLNPs monitored under excitation at 650 nm without filter and any UV pre-irradiation. The UV-Vis spectra of the PLNPs have a weak absorption in visible region, indicating that the PLNPs can be activated by a 650 nm LED light.

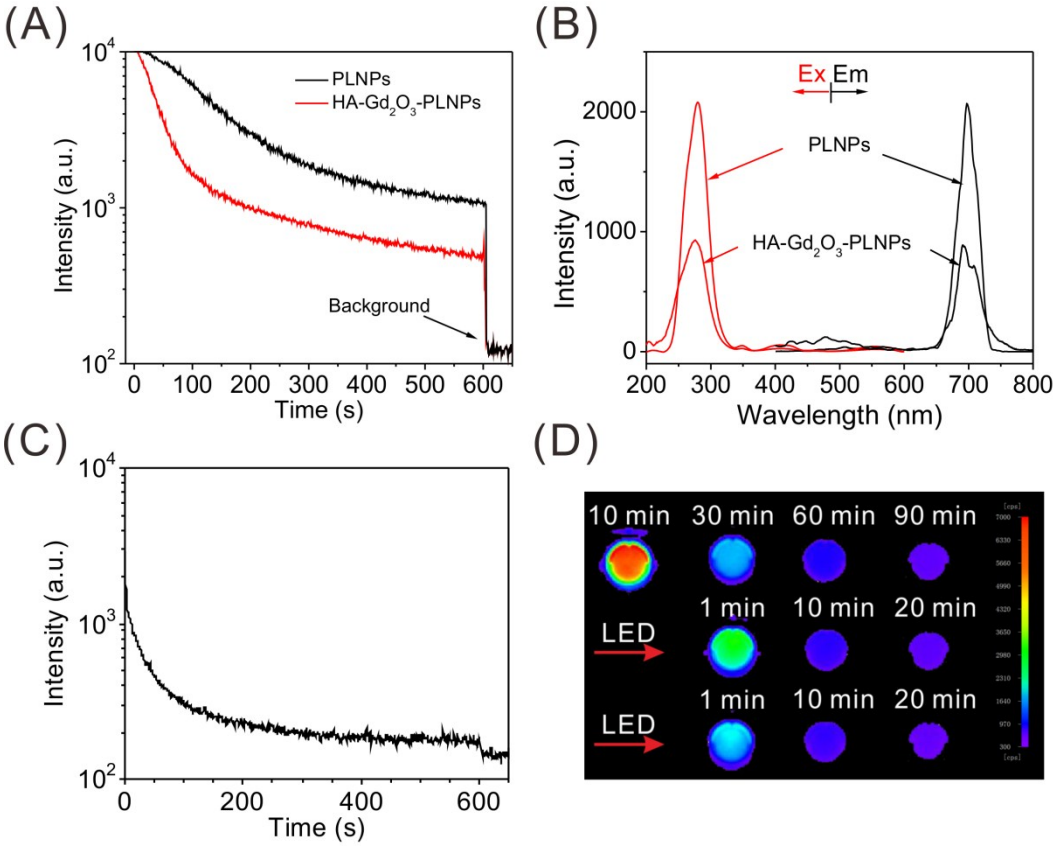

Fig. S12 (A) NIR persistent luminescence decay curves of the PLNPs and HA-Gd_2O_3-PLNPs powder after a 254 nm UV lamp excitation for 5 min. (B) Excitation and emission spectra of the PLNPs and HA-Gd_2O_3-PLNPs aqueous solution (2 mg mL^{-1}). (C) NIR persistent luminescence decay curves of HA-Gd_2O_3-PLNPs aqueous solution (2 mg mL^{-1}) after a 254 nm UV lamp excitation for 5 min. (D) Persistent luminescence images of the HA-Gd_2O_3-PLNPs aqueous solution (2 mg mL^{-1}) after excitation with a 254 nm UV lamp for 10 min and re-activation with a red LED light for 2 min. The exposure time was set as 30 s.

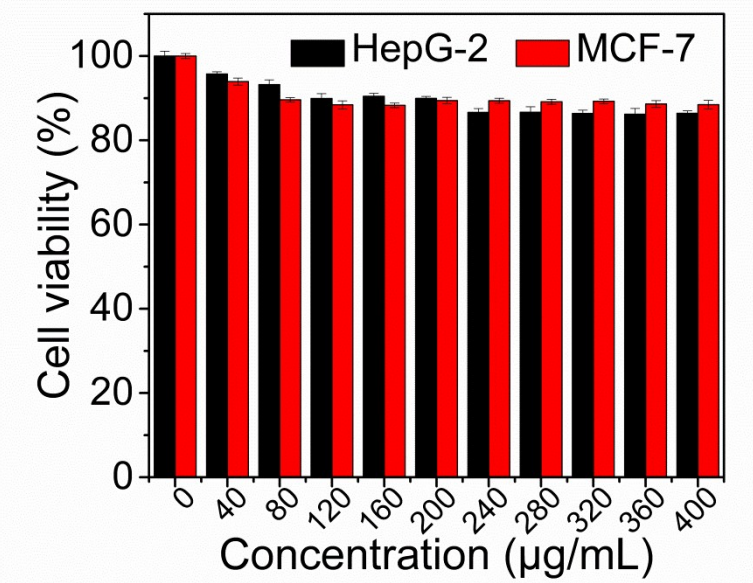

Fig. S13 Cell viability of HepG 2 and MCF-7 cells incubated with HA-Gd_2O_3-PLNPs at different concentrations for 24 h.

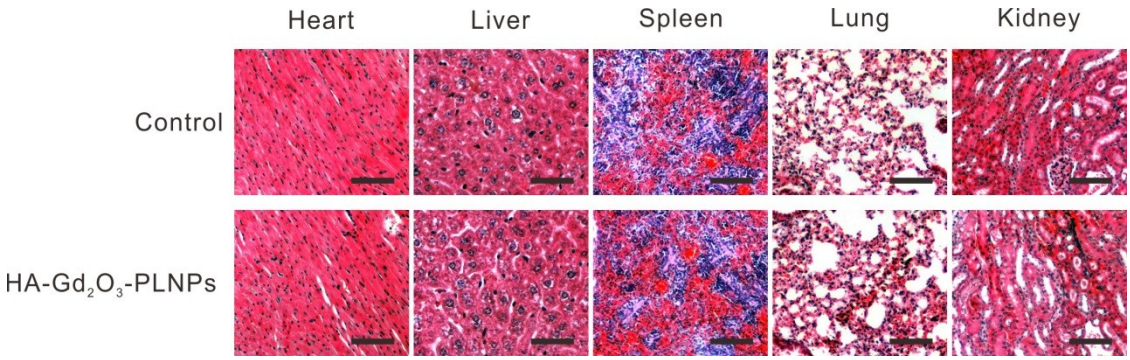

Fig. S14 Representative H&E stained images of major organs including heart, liver, spleen, lung, and kidney collected from HA-Gd_2O_3-PLNPs (200µL, 4 mg mL^{-1}) injected mice (n= 3) and the normal mice (n = 3, injected with PBS) on day 15 after tail vein injection. Scale bar is 100 µm.

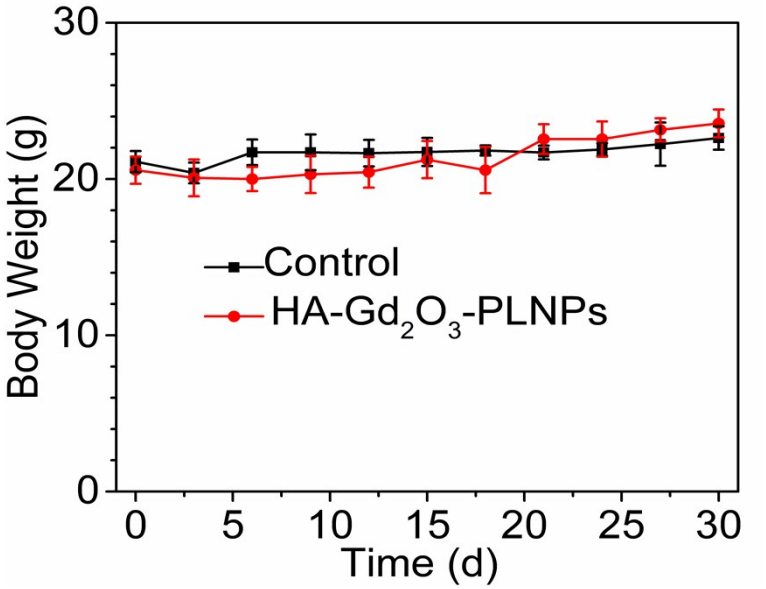

Fig. S15 Body weight changes of the mice (n=3) treated with HA-Gd_2O_3-PLNPs. The PBS injected mice (n=3) served as control.