Electronic Supplementary Material

Color Tunable Gd-Zn-Cu-In-S/ZnS Quantum Dots for Dual Modality Magnetic Resonance and Fluorescence Imaging

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Materials Characterization

The Shimadzu UV-2450 spectrophotometer is used to record the UV-vis spectra of the QDs. The PL emission spectra of QDs were recorded on a Gangdong F-280 spectrofluorometer. PL QYs were calculated by comparing the integrated PL intensity of QDs sample and standard dye solutions. Both the QDs and dye solutions are adjusted to the same absorption intensity (0.05~0.1) at the excitation wavelength. Rhodamin 6G (95% in ethanol) is selected to estimate the PL QYs of QDs with emission wavelength less than 650 nm, while Cy5.5 (28% in ethanol) is used to measure the QYs of QDs with longer emission wavelength [1-3]. TEM samples are prepared by dropping dilute QDs solutions in chloroform onto the carbon-coated copper grids. TEM images are aquired on a Tecnai G2 F20 instrument with 200 kV. X-Ray diffraction (XRD) patterns are recorded by a Rigaku Ultima III diffractometer with a rotating anode and a Cu-Ka radiation source. The Gd concentration and element components of the obtained QDs are determined by inductively coupled plasma mass spectrometry (ICP-MS). The hydrodynamic diameters of the GZCIS/ZnS@BSA nanohybrids are measured by dynamic laser scattering size analyzer (Nano ZS, Malvern) in ultrapure water, PBS (1X) and human serum.

Fabrication of ZCIS/ZnS QDs

The mixed metal oleate complexes of $Cu(OA)_2$ (0.1 mmol), $In(OA)_3$ (0.2 mmol), $Zn(OA)_2$ (0.1 mmol) and oleic acid (0.5 mL) were mixed with ODE (10 mL) in a four-necked flask. The reaction mixture was degassed under

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vacuum for 30 min and purged with argon. The reaction solution was heated to 120 °C. When the solution became clear, 1 mL of DDT was injected into the reaction system. At the moment of injection, the color of the solution changed into bright yellow. Then, sulfur precursor (9.7 mg, 0.3 mmol) dissolved in 0.5 mL of oleylamine and 1 mL of ODE solution was quickly injected into the reaction mixture at 205 °C. The reaction mixture was held at 200 °C for 120 min. Then the mixture was cooled to room temperature. Without purification, 4 mL of raw GZCIS QDs solution, 5 mL of ODE and 1 mL of DDT were loaded into a four-necked flask. 0.1 mmol of $Zn(Ac)_2$ in ODE/oleylamine(v/v, 4/1, in 1 mL) was injected into the flask under vigorous stirring at room temperature. The mixture was then kept at 220 °C for 20 min to allow the growth of the ZnS shell. The same procedure was repeated for another four times to obtain highly fluorescent ZCIS/ZnS QDs.

In Vitro Relaxometry

The relaxation times were measured using a 1.5 T mini specmq 60 NMR Analyzer (Bruker, Germany) at 37 °C. The in vitro cellular MR images were obtained using a MicroMR-25 mini MRI system (Niumag Corporation, Shanghai, China). The measurement conditions were as follows: T1-weighted sequence: spin echo, TR/TE = 100.0/1.0 ms, matrix acquisition = 96×96, NS = 2, FOV = 22 mm × 22 mm, thickness = 5 mm, 0.535 T, 34.0 °C.

Cell uptake and In Vitro Imaging

HeLa cells were incubated with GZCIS/ZnS@BSA nanoclusters at 37°C in an atmosphere of 5% CO_2 and 95% air for 6 h. Then, the cells were washed several times with PBS buffer and prepared for fluorescence cellular imaging. Following the fluorescence imaging, the corresponding cells were isolated by trypsin (0.25%), centrifuged and subsequently redispersed in 1 mL of PBS buffer. Tubes containing the collected PBS buffer were prepared for MR imaging as described before.

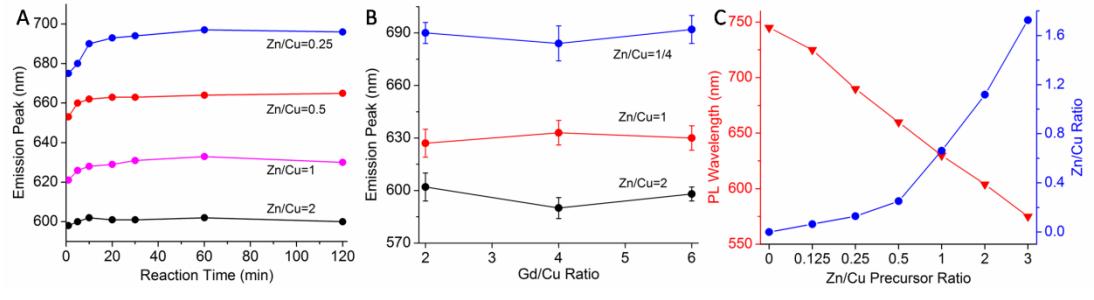

Figure S1 A, Temporal evolution of PL peaks of the ZCIS QDs synthesized with various Zn/Cu feeding ratios. B, PL peaks of GZCIS QDs synthesized with various Zn/Cu and Gd/Cu ratios.Gd/Cu feed ratio has little effect on the PL emission peaks of the GZCIS QDs if the Zn/Cu ratio is fixed. C, PL emission peaks and corresponding compositions of GZCIS QDs obtained at various Zn/Cu feed ratios with Gd/Cu feed ratio fixed at 2/1.

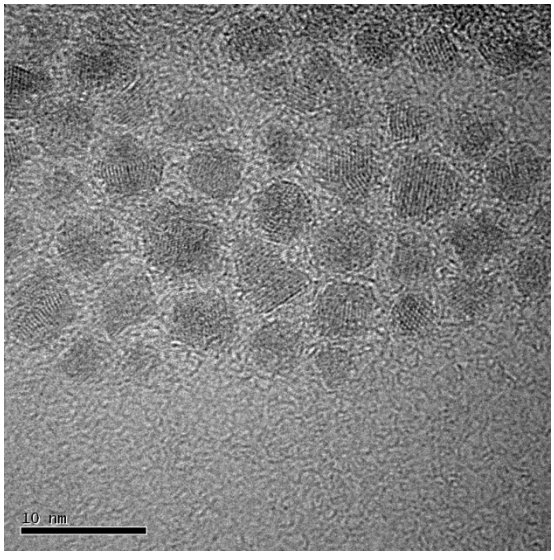

Figure S2 The TEM image of GZCIS/ZnS core shell QDs.

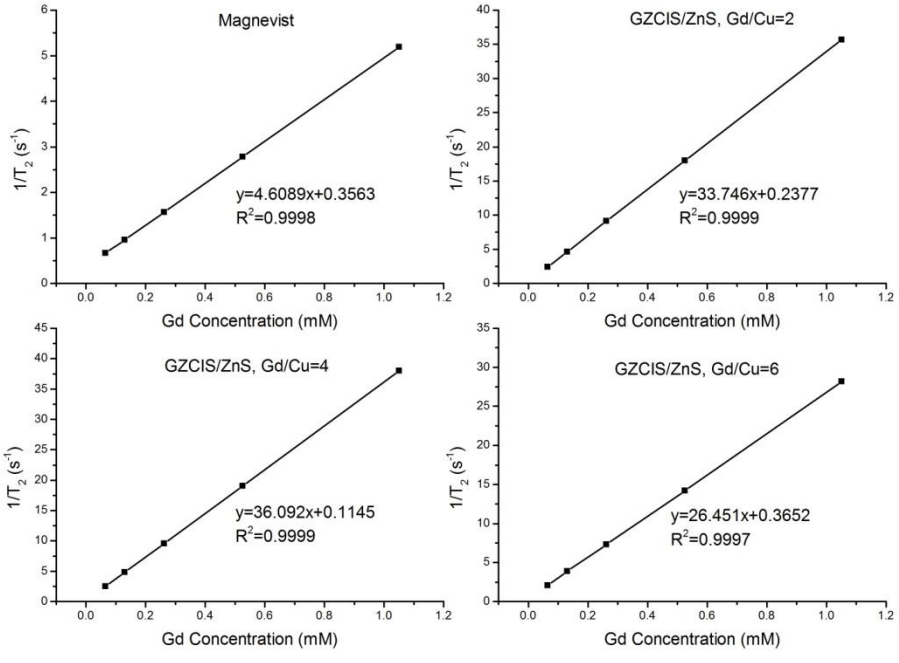

Figure S3 The linear relationship between T_2 relaxation rate ($1/T_2$) and Gdcation concentration for Magnevistand GZCIS/ZnS with different Gd/Cu ratios.

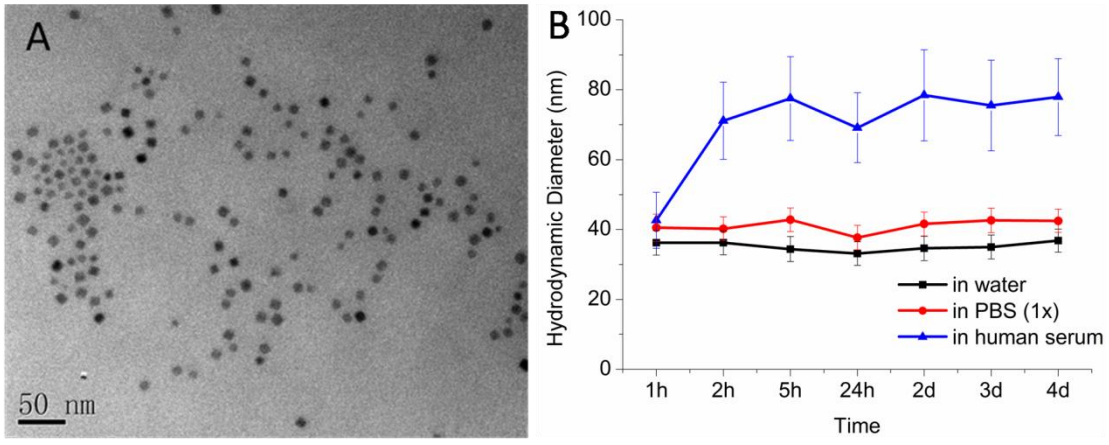

Figure S4 A, the TEM image of GZCIS/ZnS@BSA nanohybrids in water. B, the temporal evolution of the hydrodynamic diameter of GZCIS/ZnS@BSA nanohybrids dispersed in water, PBS (1X) and human serum solution, respectively.

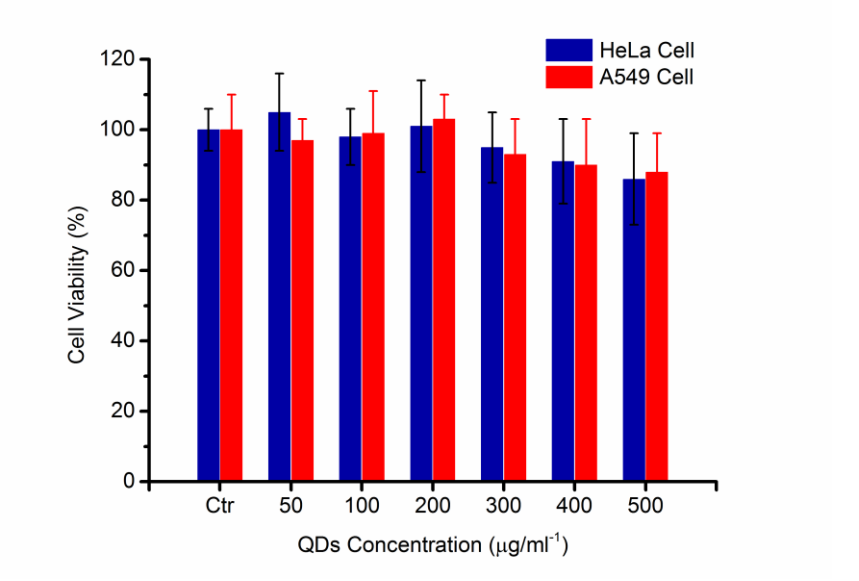

Figure S5 The viability of HeLa and A549 cells After incubation with BSA coated GZCIS/ZnS bimodal QDs for 24 h. The viability was measured using 3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay and normalized to cells grown in the absence of any nanoparticles.

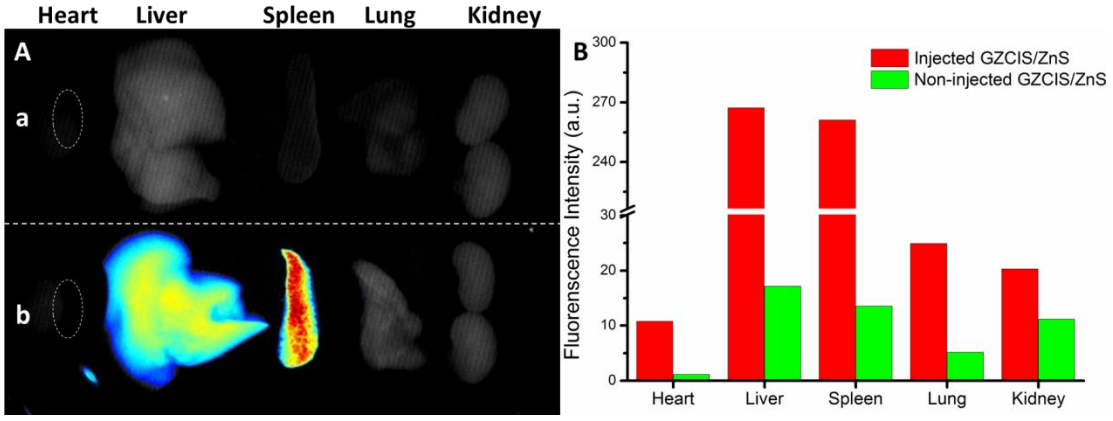

Figure S6 A, the ex vivo fluorescence image of organs derived from the mice without (a) and with (b) injection of the GZCIS/ZnS QDs. B, ROI analysis of major organs in ex vivo fluorescence imaging at 6 h after intravenous injection of BSA coated GZCIS/ZnS bimodal QDs at a dose of 0.05 mmol Gd/kg. The data were represented as mean intensity.

Reference

[1] Xie, R.; Zhong, X.; Basché, T. Synthesis, characterization, and spectroscopy of type-II core/shell semiconductor nanocrystals with ZnTe cores. *Advanced Materials*. **2005,** *17* (22), 2741-2745.

[2] Xing, B.; Li, W.; Wang, X.; Dou, H.; Wang, L.; Sun, K.; He, X.; Han, J.; Xiao, H.; Miao, J. Highly-fluorescent alloyed quantum dots of $CdSe_{1-x}Te_x$ synthesized in paraffin liquid: gradient structure and promising bio-application. *Journal of Materials Chemistry*. **2010,** *20* (27), 5664-5674.

[3] Grabolle, M.; Spieles, M.; Lesnyak, V.; Gaponik, N.; Eychmüller, A.; Resch-Genger, U. Determination of the fluorescence quantum yield of quantum dots: suitable procedures and achievable uncertainties. *Analytical Chemistry*. **2009,** *81* (15), 6285-6294.