**Supporting Information** 

## Full-spectrum responsive ZrO<sub>2</sub>-based phototheranostic agent for

## NIR-II photoacoustic imaging-guided cancer phototherapy

Chengyuan Zhu<sup>+</sup>, Zhaoyang Ding<sup>+</sup>, Zhengxi Guo, Xiaolu Guo, Aijia Yang, Zhilang Li, Bang-Ping Jiang<sup>\*</sup>

and Xing-Can Shen\*

State Key Laboratory for the Chemistry and Molecular Engineering of Medicinal Resources, College of

Chemistry and Pharmaceutical Science, Guangxi Normal University, Guilin, 541004, P. R. China.

\*Corresponding Author: xcshen@mailbox.gxnu.edu.cn; jiangbangping@mailbox.gxnu.edu.cn.

<sup>+</sup>These authors contribute equally to the work.



**Fig. S1** (a) Time-dependent photographs of  $ZrO_{2-x}$ -B in water, saline, PBS, DMEM, DMEM + Serum, RPMI-1640, and RPMI-1640 + Serum respectively. (b) Time-dependent hydrodynamic size of  $ZrO_{2-x}$ -B in water, saline, PBS, DMEM, DMEM + Serum, RPMI-1640, and RPMI-1640 + Serum, respectively.



Fig. S2 FT-IR spectra of HA, ZrO<sub>2-x</sub>-B@SiO<sub>2</sub>, and ZrO<sub>2-x</sub>-B@SiO<sub>2</sub>-HA.



**Fig. S3** (a) Photothermal images of  $ZrO_{2-x}$ -B (50 µg mL<sup>-1</sup>) upon exposure to a 1064 nm laser (1.0 W cm<sup>-2</sup>) for various time periods. (b) Time-dependent photothermal curves of  $ZrO_{2-x}$ -B.

4

**Journal Name** 



Fig. S4 Laser wavelength-dependent photothermal curves of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>).



**Fig. S5** (a) Photothermal images of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>) and pure water upon exposure to a 638 nm laser (1.0 W cm<sup>-2</sup>) for various time periods. (b) Time-dependent photothermal curves of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA at different concentrations. (c) Temperature variations of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>) upon exposure to the 638 nm laser (1.0 W cm<sup>-2</sup>) for five cycles (10 min of irradiation for each cycle). (d) Photothermal conversion efficiency under irradiation with a 638 nm laser and the fitted cooling curve. (e) Plot of cooling time versus the negative natural logarithm of the temperature driving force obtained from the cooling stage.



**Fig. S6** (a) Photothermal images of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>) and pure water upon exposure to an 808 nm laser (1.0 W cm<sup>-2</sup>) for various time periods. (b) Time-dependent photothermal curves of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA at different concentrations. (c) Temperature variations of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>) upon exposure to the 808 nm laser (1.0 W cm<sup>-2</sup>) for five cycles (10 min of irradiation for each cycle). (d) Photothermal conversion efficiency under irradiation with an 808 nm laser and the fitted cooling curve. (e) Plot of cooling time versus the negative natural logarithm of the temperature driving force obtained from the cooling stage.



**Fig. S7** Temperature elevations of aqueous of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA (125 µg mL<sup>-1</sup>) upon exposures to tissue-Penetrating 638, 808, and 1064 nm laser.



**Fig. S8** UV–visible spectra of NBT under (a) 638, (c) 808, and (e) 1064 nm laser irradiation. UV–visible spectra of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA with NBT under (b) 638, (d) 808, and (f) 1064 nm laser irradiation.



ARTICLE



**Fig. S9** Fluorescence spectra of TA under (a) 638, (c) 808, and (e) 1064 nm laser irradiation. Fluorescence spectra of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA with NBT under (b) 638, (d) 808, and (f) 1064 nm laser irradiation.



**Fig. S10** Fluorescence images of 4T1, Hela, and L929 cells after incubated by  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA-RhB for 6 h. Scale bar: 40  $\mu$ m



Journal Name



**Fig. S11** (a) Relative cell viability of L929, Hela and 4T1 cells incubated with various concentrations of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA with laser irradiation (1064 nm, 1.0 W cm<sup>-2</sup>) a 4 °C environment. (b) Relative cell viability of L929, Hela and 4T1 cells incubated with Vitamin C and various concentrations of  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA with laser irradiation (1064 nm, 1.0 W cm<sup>-2</sup>).



**Fig. S12** (a) *In vivo* fluorescence images of mice at different time points after intravenous injection of Rhodamine B or  $ZrO_{2-x}$ -B@SiO<sub>2</sub>-HA-RhB. (b) *Ex vivo* fluorescence images of major organs and tumours at 24 h injection.

ARTICLE



**Fig. S13** Infrared thermal mapping of 4T1 tumour-bearing mice under laser irradiation (1064 nm, 1.0 W  $\text{cm}^{-2}$ , 5 min) intravenously injected saline and  $\text{ZrO}_{2-x}$ -B@SiO<sub>2</sub>-HA.



Fig. S14 Photographs of tumour tissues