

## Supplementary Material

### **Tumor reoxygenation for enhanced combination of radiation therapy and microwave thermal therapy using oxygen generation in situ by CuO nanosuperparticles under microwave irradiation**

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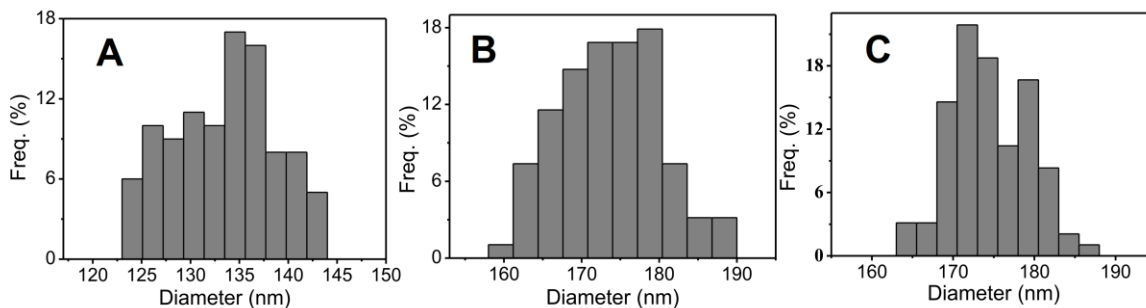
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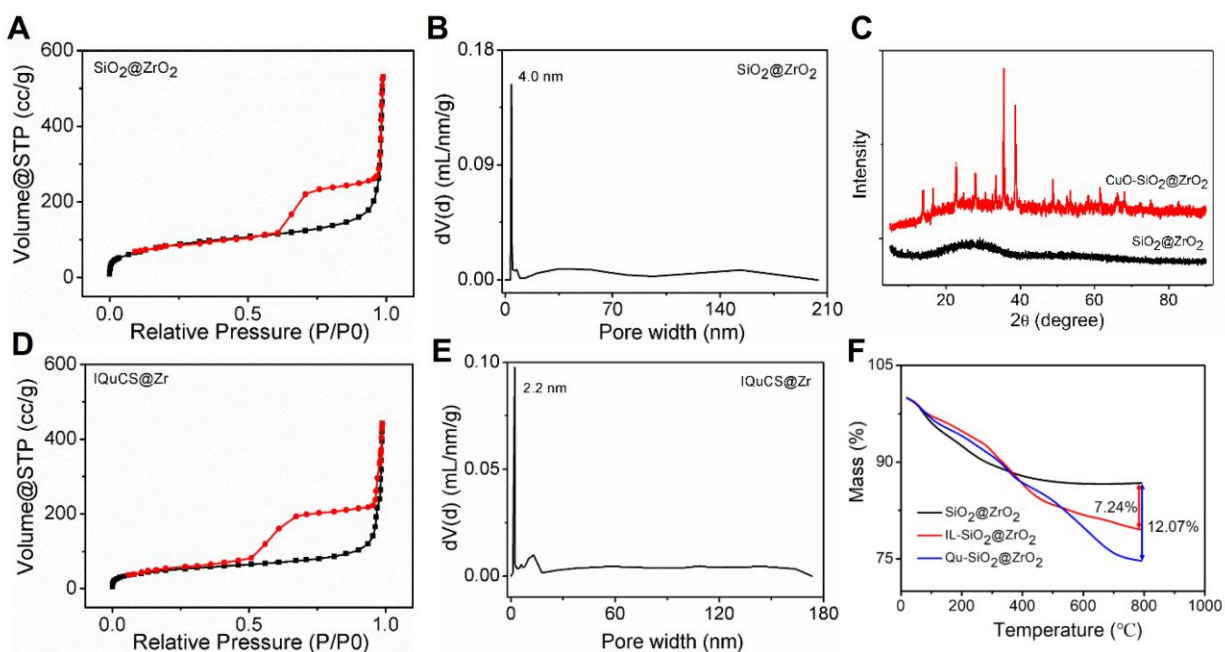
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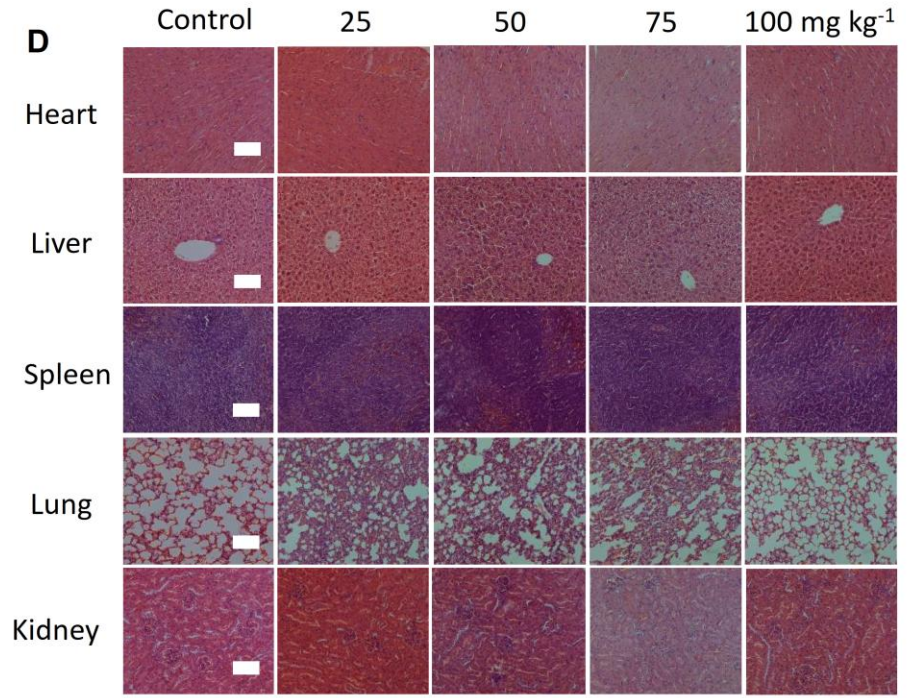
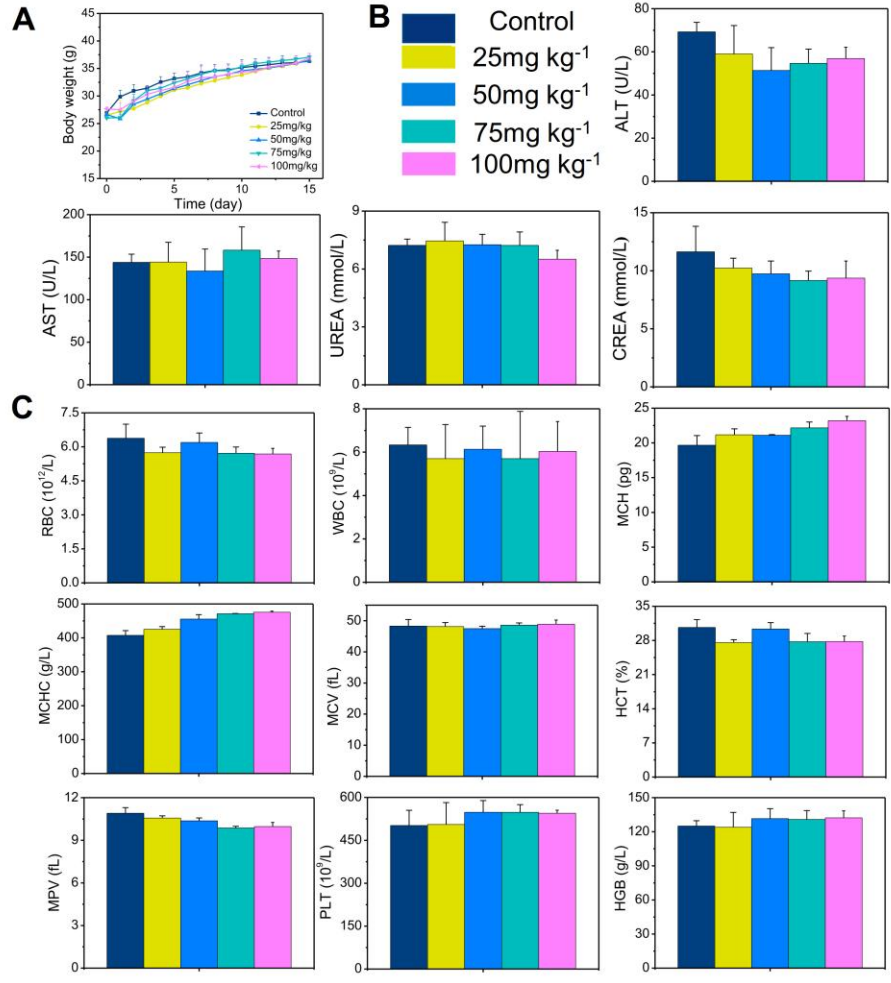
## Figures in supplementary material



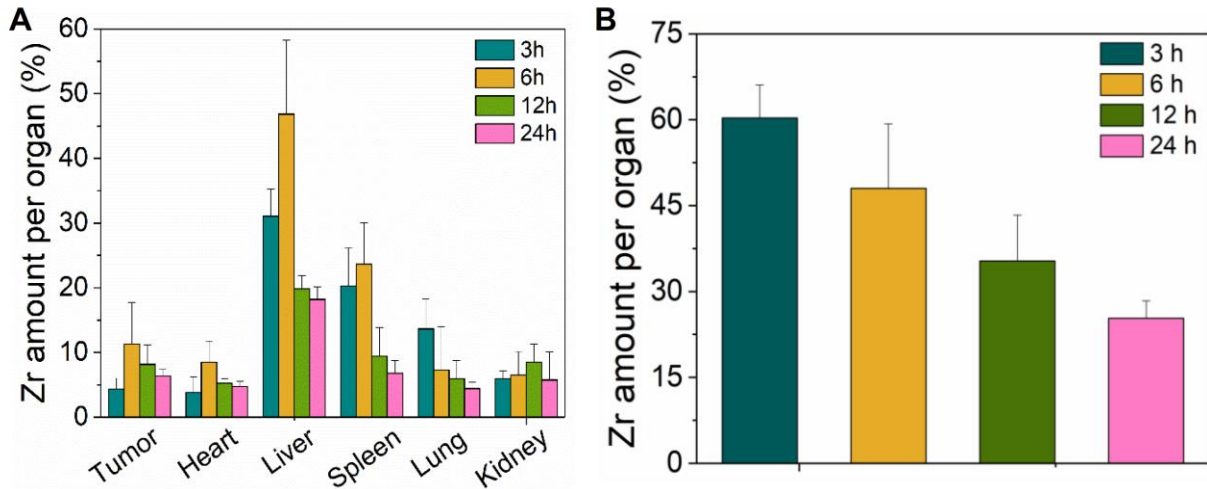
**Figure S1.** Characterization of the IQuCS@Zr-PEG NSPs. (A) Particle size distribution of SiO<sub>2</sub> nanoparticles. (B) Particle size distribution of SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs. (C) Particle size distribution of CuO-SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs.



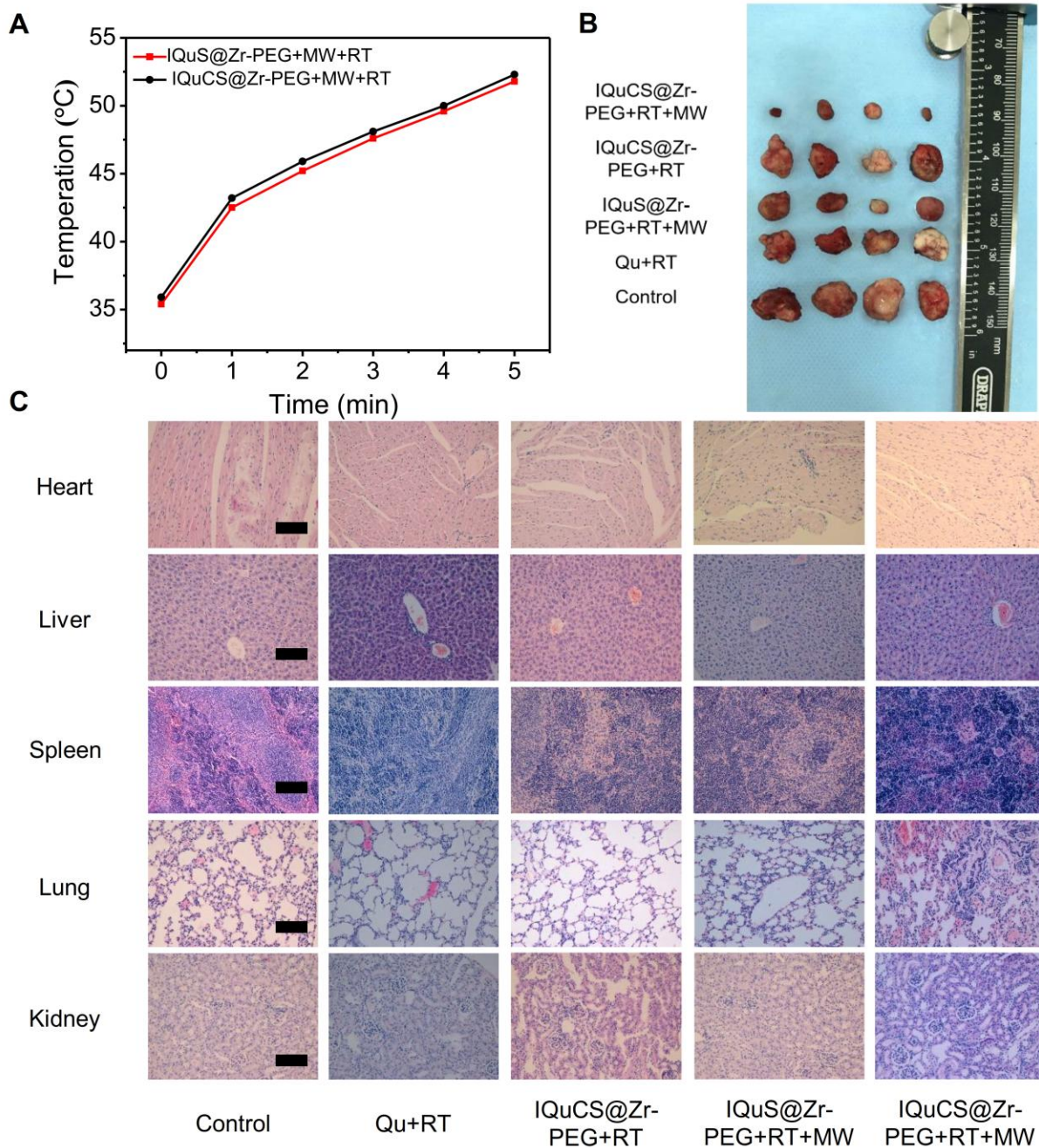
**Figure S2.** The specific surface area and pore diameter of the SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs and IQuCS@Zr NSPs, The XRD analysis of SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs and CuO-SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs. (A) The specific surface area of the SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs. (B) The pore diameter of the SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs. (C) The XRD analysis of SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs and CuO-SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs. (D) The specific surface area of the IQuCS@Zr NSPs. (E) The pore diameter of the IQuCS@Zr NSPs. (F) TGA results of SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs, IL-SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs and Qu-SiO<sub>2</sub>@ZrO<sub>2</sub> NSPs.



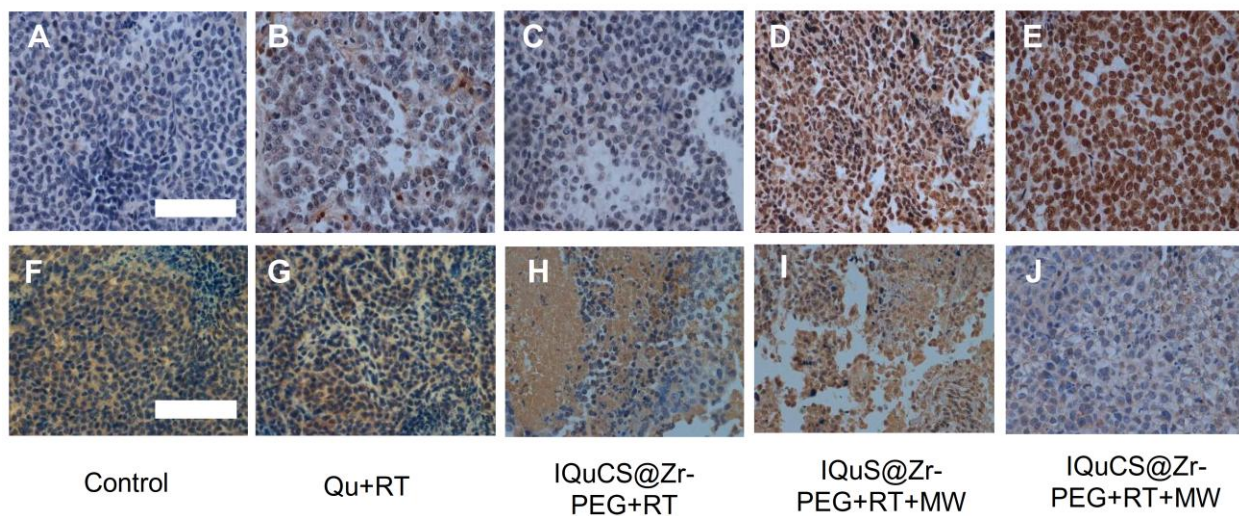
**Figure S3.** Biocompatibility evaluation. (A) Changes in body weight in mice after intravenous administration of IQuCS@Zr-PEG NSPs at different concentrations. (B) Serum biochemical analysis in mice after intravenous administration of IQuCS@Zr-PEG NSPs at different concentrations results. (C) Routine blood examination results of mice injected with different concentrations of IQuCS@Zr-PEG NSPs intravenously. (D) Different concentrations of IQuCS@Zr-PEG NSPs after intravenous injection tissue H&E staining results. The scale bar is 50  $\mu\text{m}$ .



**Figure S4.** Zr element distribution in vivo. (A) Distribution of Zr in tumors and major tissues from mice at 3 h, 6 h, 12 h and 24h after injection (the dose of IQuS@Zr-PEG NSPs was 50 mg/kg, n=3). (B) Distribution of Zr in blood from mice at 3 h, 6 h, 12 h and 24h after injection (the dose of IQuS@Zr-PEG NSPs was 50 mg/kg, n=3).



**Figure S5.** Evaluation of *in vivo* therapeutic experiments of IQuCS@Zr-PEG NSPs. (A) Temperature change curve per minute for treatment experiments. (B) Photographs of tumor tissues treated on the 14th day of each experimental mouse. (C) H&E staining sections of major organs after treatment for 14 days in each experimental mouse. The scale bar is 50  $\mu$ m.



**Figure S6.** Experimental results of TUNEL and immunohistochemistry. (A-E) Figures A to E were the TUNEL results of the tumor tissues in the control group, Qu+RT group, IQuCS@Zr-PEG+RT group, IQuS@Zr-PEG+RT+MW group, and IQuCS@Zr-PEG+RT+MW group, respectively (magnification 400 $\times$ ). (F-J) Figures F to J were the immunohistochemistry results of the tumor tissues in the control group, Qu+RT group, IQuCS@Zr-PEG+RT group, IQuS@Zr-PEG+RT+MW group, and IQuCS@Zr-PEG+RT+MW group, respectively (magnification 400 $\times$ ). The scale bar is 50  $\mu$ m.