Supporting information

Nanostructures based on vanadium disulfide growing on UCNPs: simple synthesis, dual-mode imaging, and photothermal therapy

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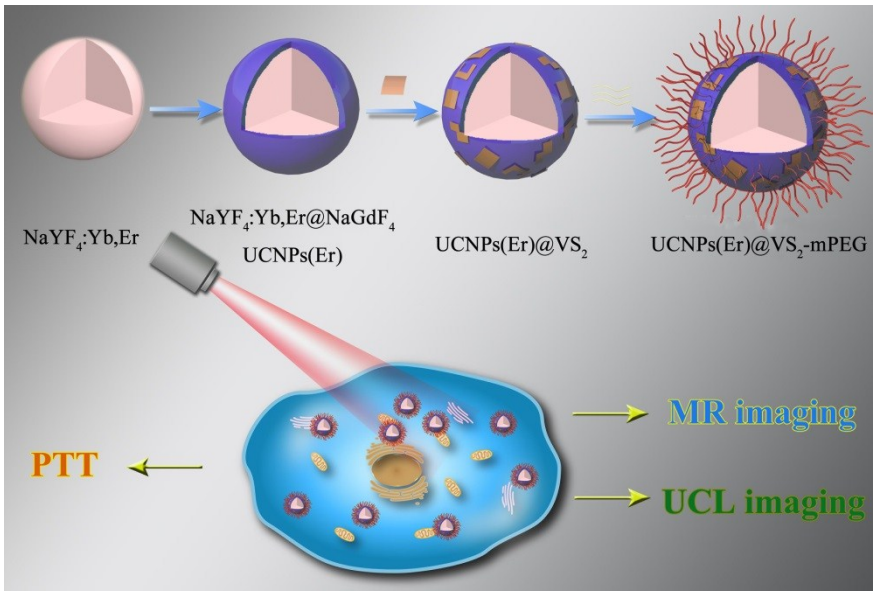
(1) Synthesis of Oleic Acid (OA) coated $NaYF_4$:Yb,Er and $NaYF_4$:Yb,Tm.

2 mmol of $LnCl_3$ (Ln: 78 mol %Y+20 mol %Yb+2 mol %Er, or 80 mol %Y+20 mol %Yb+0.5 mol %Tm) in deionized water were added into 100 mL three-neck round-bottom flask, and then the solution was heated to 110 °C to remove the water to get the white solid. After 12 mL oleic acid (OA, 90%) and 30 mL 1-octadecane (ODE, 90%) were added in sequence, the solution was heated to 150 °C to form transparent yellow solution, and then cooled down to 60 °C. Following, 20 mL methanol containing NaOH (5 mmol, 0.2 g) and NH_4F (8 mmol, 0.3 g) were added in, stirring at 110 °C to evaporate methanol and water. Finally, the reaction solution was directly heated to 300 °C and maintained the temperature for 1 h under Argon. After the reaction was completed, raw products was obtained with centrifugation in the adding of ethanol, and washed with cyclohexane and ethanol twice times. The samples (OA coated $NaYF_4$:Yb,Er or $NaYF_4$:Yb,Tm) were re-dispersed in 20 mL of cyclohexane, respectively.

(2) Synthesis of oleic acid modified UCNPs and UCNPs(Er).

$GdCl_3$ solution (1 M, 800 μL)was added into 100 mL three-neck round-bottom flask, and heated to 110 °C to evaporate the water until white powder was obtained. Then 15 mL of OA and 30 mL of ODE were added to dissolve the white powder, heated to 150 °C and maintained for 10 min, then cooled to 60 °C. Next, 20 mL methanol containing NH_4F (0.039 g, 1.05 mmol) and NaOH (0.067 g, 1.68 mmol) and 5 mL $NaYF_4$:Yb,Er or $NaYF_4$:Yb,Tm were added in. The dispersion liquid was heated to 110 °C to remove methanol and cyclohexane for 30 min. The resultant solution reacted in 300 °C under Argon for 1 h. The purification disposal was similar to the method mentioned above. The obtained samples were dispersed in 10 mL of cyclohexane for further application. In this case, two kinds of nanoparticles were synthesized, $NaYF_4$:Yb,Tm@$NaGdF_4$ (Y:Yb:Tm = 80:20:0.5) and $NaYF_4$:Yb,Er@$NaGdF_4$ (Y:Yb:Er = 78:20:2), named as UCNPs and UCNPs(Er), respectively.



Scheme S1. Schematic illustration of the synthesis of UCNPs(Er)@VS_2-mPEG nanostructure, as well as its dual-mode imaging and laser-induced photothermal therapy. (Laser: 980 nm for UCL imaging and 808 nm for PTT effect).

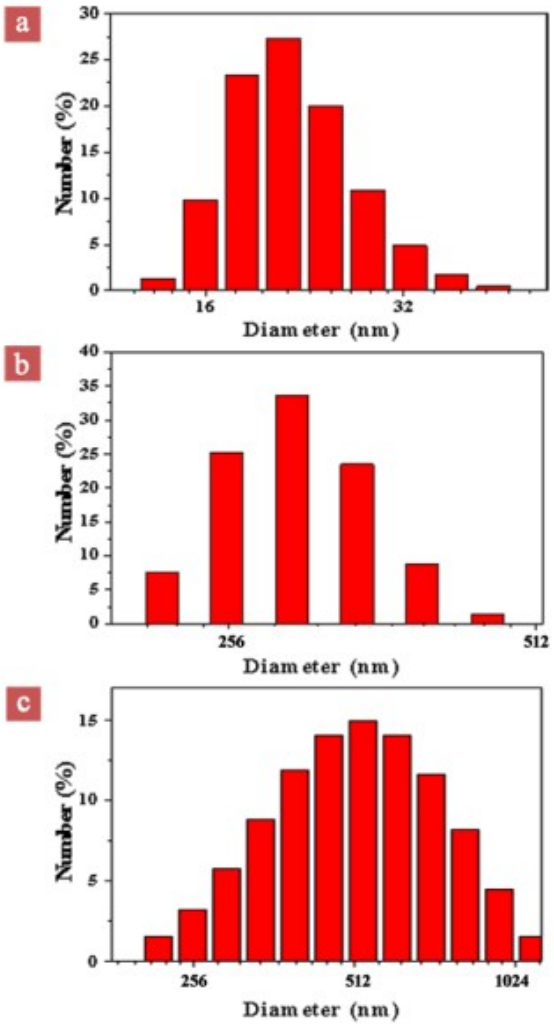


Fig. S1. Dynamic light scattering (DLS) size of (a) UCNPs, (b) UCNPs@VS_2, and (c) UCNPs@VS_2-mPEG.

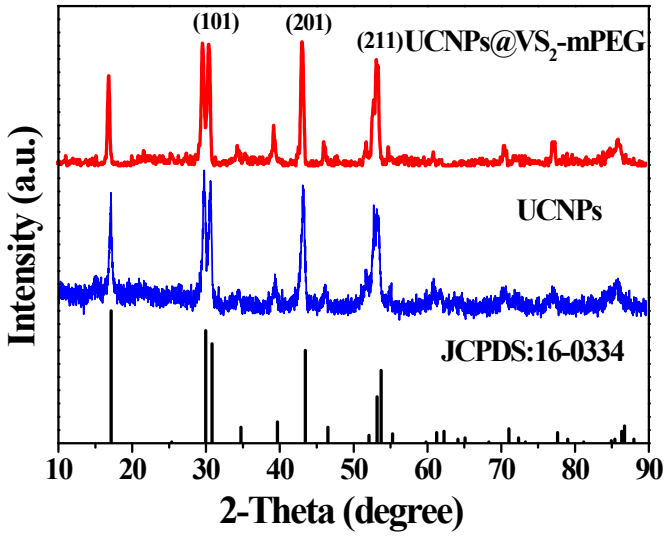


Fig. S2. XRD patterns of UCNPs, UCNPs@VS_2-mPEG, and the standard card of β-$NaYF_4$ (JCPDS: 16-0334).

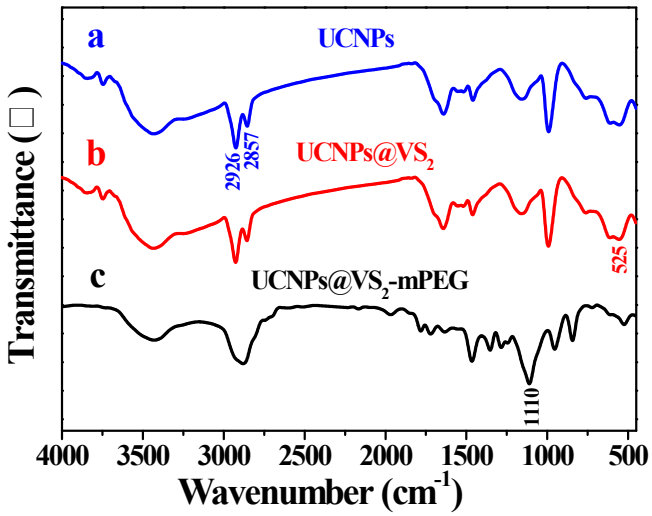


Fig. S3. FT-IR spectra of (a) UCNPs, (b) UCNPs@VS_2 and (c) UCNPs@VS_2-mPEG.

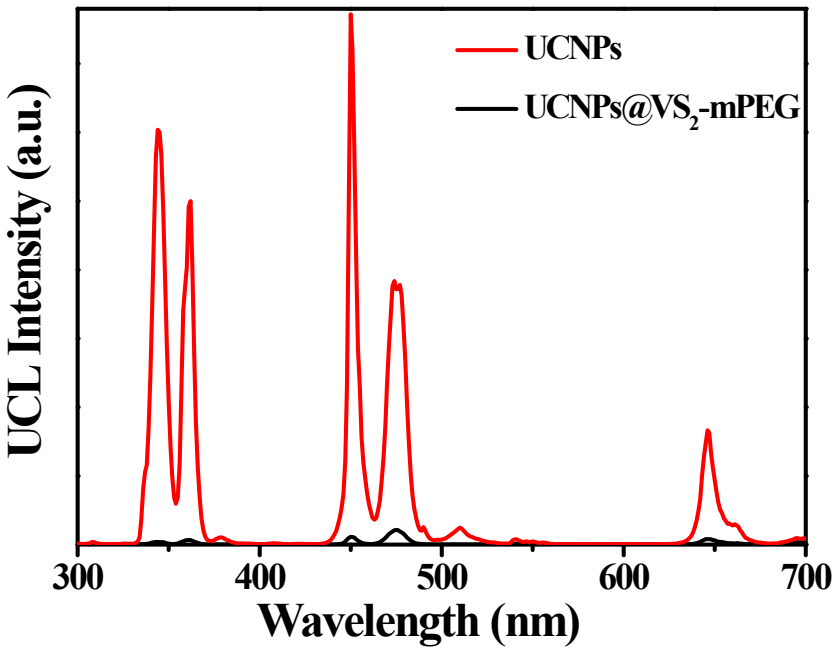


Fig. S4. The upconversion luminescence (UCL) spectra of UCNPs and UCNPs@VS_2-mPEG (under excitation by using a 980 nm laser, 1.5 W/cm^2).

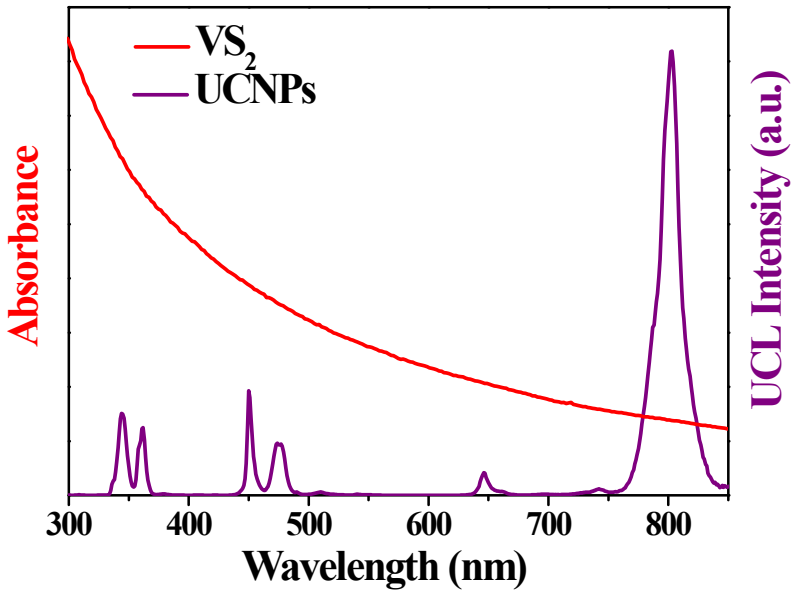


Fig. S5. Spectral overlap between the upconversion luminescence (UCL) spectrum of UCNPs (purple line) and absorption spectrum of VS_2 (red line).

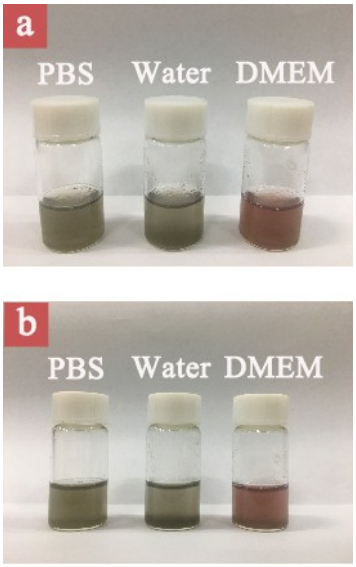


Fig. S6. The photographs of UCNPs@VS_2-mPEG dispersed in PBS, water, and DMEM culture medium at the first day (a) and after 7 days (b). There is no obvious aggregation after 7 days.

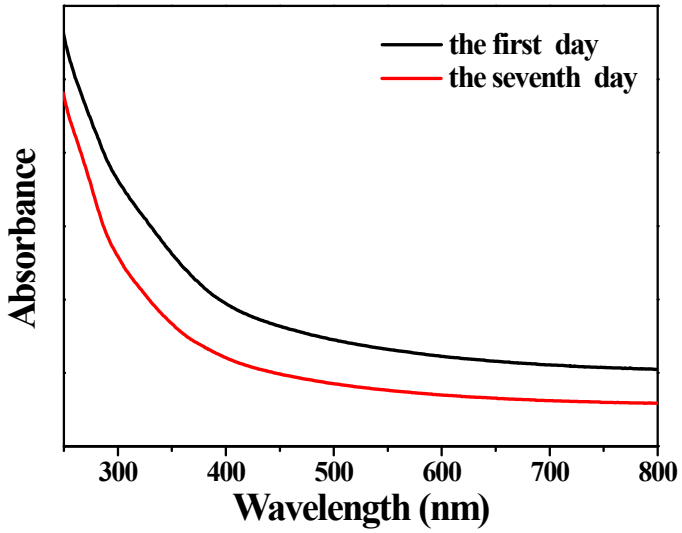


Fig. S7. The absorption spectra of UCNPs@VS_2-mPEG dispersed in water at the first day and after 7 days.