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Electronic Supplementary Information

Doxorubicin-conjugated CuS nanoparticles for efficient synergistic therapy triggered by near-infrared light

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The rough calculations process of the number of DOX molecules released from per CuS-DOX.

The number of DOX molecules released from per CuS-DOX in the sample was determined according to previous method.[1] We obtained the standard curve of DOX, y = 18.327x+0.001. In order to determine the density and content, according to the standard curve, the release amount of DOX from nanoparticles can be calculate:

The initial concentration of DOX is 0.5 mg/mL, and the absorbance of supernatant after loading is 8.065. The Cu^{2+}concentration of CuS-DOX NPs is about 2.8 μg/mL obtained by ICP-MS.

Loaded concentration ΔX = 0.5 mg/mL-(8.065-0.001)/18.327 = 0.44 mg/mL.

The number of DOX can be calculate：

$$n_{DOX} = \frac{0.44\ mg/mL}{1000 \times 577.99 g/mol} \times 6.02\times10^{23}/\text{mol} = 4.58\times10^{17}/\text{mL}$$

The quality of CuS: $m_{CuS} = \rho V = 4.6\ \text{g/cm}^3 \times \frac{4}{3}\pi(5\text{nm}\times10^{-7})^3 = 7.67\times10^{-19}\ \text{g}$

$$n_{CuS} = \frac{2.8 \mu g/mL}{7.67 \times 10^{-19} g} = 3.65\times10^{12}/\text{mL}$$

$$R_{DOX} = \frac{4.58 \times 10^{17}/mL}{3.65 \times 10^{12}/mL} = 1.25\times10^{5}$$

About 1.25×10^5 of DOX molecules were released from per particle after 24 hour.

The calculation of the photothermal conversion efficiency.

The photothermal conversion efficiency of CuS was determined according to previous method.[2,3] Detailed calculation was given as following:

Based on the total energy balance for this system:

$$\sum_i m_i C_{p,i} \frac{dT}{dt} = Q_{NPs} + Q_s - Q_{loss} \qquad (1)$$

m and C_p are the mass and heat capacity of solvent (water). T is the solution temperature.

Q_{NPs} is the photothermal energy input by CuS:

$$Q_{NPs} = I(1 - 10^{-A_\lambda})\eta \qquad (2)$$

I is the laser power, A_λ is the absorbance of CuS at the wavelength of 808 nm, and η is the conversion efficiency from the absorbed light energy to thermal energy. $A_\lambda = \in_\lambda Lc$, where $\in_\lambda$ is the wavelength-dependent molar absorptivity, L is path length, and c is molar concentration.

Q_s is the heat associated with the light absorbance of the solvent, which is measured independently to be $Q_s = (5.4 \times 10^{-4}) I \, J \, s^{-1}$ using pure water without CuS.

Q_{loss} is thermal energy lost to the surroundings:

$$Q_{loss} = hA\Delta T \qquad (3)$$

h is the heat transfer coefficient, A is the surface area of the container, and ΔT is the temperature change, which is defined as $T - T_{surr}$(T and T_{surr} are the solution temperature and ambient temperature of the surroundings, respectively).

At the maximum steady-state temperature, the heat input is equal to the heat output, that is:

$$Q_{NPs} + Q_s = Q_{loss} = hA\Delta T_{max} \qquad (4)$$

ΔT_{max} is the temperature change at the maximum steady-state temperature. According to the Eq.2 and Eq.4, the photothermal conversion efficiency (η) can be determined:

$$\eta = \frac{hA\Delta T_{max} - Qs}{I(1 - 10^{-A_\lambda})} \qquad (5)$$

In this equation, only hA is unknown for calculation. In order to get the hA, we herein introduce θ, which is defined as the ratio of ΔT to ΔT_{max}:

$$\theta = \frac{\Delta T}{\Delta T_{max}} \qquad (6)$$

Substituting Eq.6 into Eq.1 and rearranging Eq.1:

$$\frac{d\theta}{dt} = \frac{hA}{\sum_i m_i C_{p,i}}\left[\frac{Q_{NPs} + Q_s}{hA\Delta T_{max}} - \theta\right] \qquad (7)$$

When the laser was shut off, the $Q_{NPs} + Q_s = 0$, Eq.7 changed to:

$$dt = -\frac{\sum_i m_i C_{p,i}}{hA}\frac{d\theta}{\theta} \qquad (8)$$

Integrating Eq.8 gives the expression:

$$t = -\frac{\sum_i m_i C_{p,i}}{hA}\ln\theta \qquad (9)$$

Thus, hA can be determined by applying the linear time data from the cooling period vs $-\ln\theta$

(Fig. S2). Substituting hA value into Eq.5, the photothermal conversion efficiency (η) of CuS solution can be calculated.

Fig. S1 CuS-DOX NPs dispersed in water before and after 24 h.

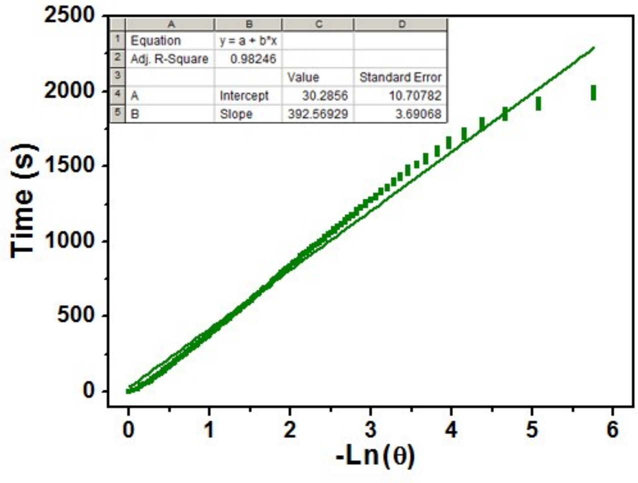

Fig. S2 Linear time data versus $-\ln\theta$ obtained from the cooling period of Fig. 2b.

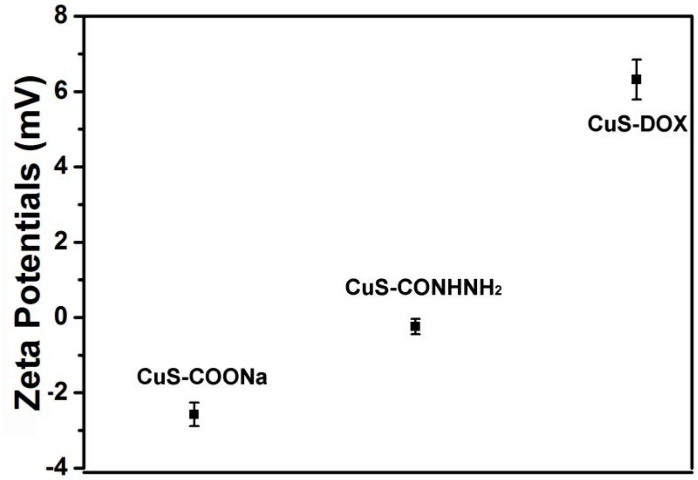

Fig. S3 Zeta potentials of CuS NPs, CuS-$CONHNH_2$ NPs and CuS-DOX NPs.

Notes and references

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