Redox responsive UCNPs-DPA conjugated NGO-PEG-BPEI for cancer theranostic

Arif Gulzar,*a Jiating Xu,a Liangge Xu,a Shili Gai,*a Piaoping Yang,*a Fei He,a Dan Yang,a Guanghui An,a Mohd Bismillah Ansariab

aKey Laboratory of Superlight Materials and Surface Technology, Ministry of Education, College of Material Sciences and Chemical Engineering, Harbin Engineering University, Harbin, 150001, P. R. China

bSaudi Basic Industries Kingdom of Saudi Arabia
Fig. S1 XRD pattern of UCNPs. The standard pattern of hexagonal phases NaGdF₄:Yb³⁺, Er³⁺@NaGdF₄ is given for reference (JCPDS No.27-0699).
**Fig. S2** FT-IR spectra of NGO-PEG and NGO. The strong stretching vibration peak of C–H (~2880 cm$^{-1}$) demonstrated the presence of PEG in the NGO-PEG. The appearance of the new absorption at ~1649 cm$^{-1}$ for –CONH– further indicated that PEG has been covalently boned on the surface of NGO successfully.
**Fig. S3** Temperature variation curves of the NGO-PEG solution subjected to the 980 nm laser at a power density of 0.72 W/cm².
**Fig. S4** LSUCLM images of HeLa cells when incubating with UCNPs-DPA-NGO-PEG-BPEI-DOX for 0.5 h, 1 h, and 3 h.
**Fig. S5** Hemolytic assay of UCNPs-DPA-NGO-PEG-BPEI-DOX by human red blood cells.
Fig. S6 (A) The photothermal response of the UCNPs-DPA-NGO-PEG-BPEI-DOX aqueous solution (200 μg/mL) radiated with 980 nm laser (0.72 W/cm²) and then the laser was shut off. (B) Linear time data versus $-\ln \theta$ obtained from the cooling period of Fig. S6A. (C) Temperature change of UCNPs-DPA-NGO-PEG-BPEI-DOX under three irradiation/cooling cycles (0.72 W/cm²).