Supporting information

An NIR-driven biosensor based on the metal-enhanced fluorescence effect and a signal amplification strategy for miRNA detection

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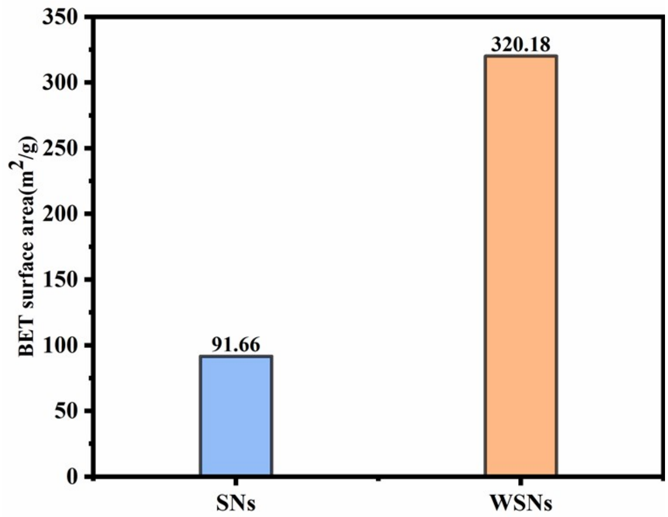

Figure S1 Specific surface areas of the SNs and WSNs

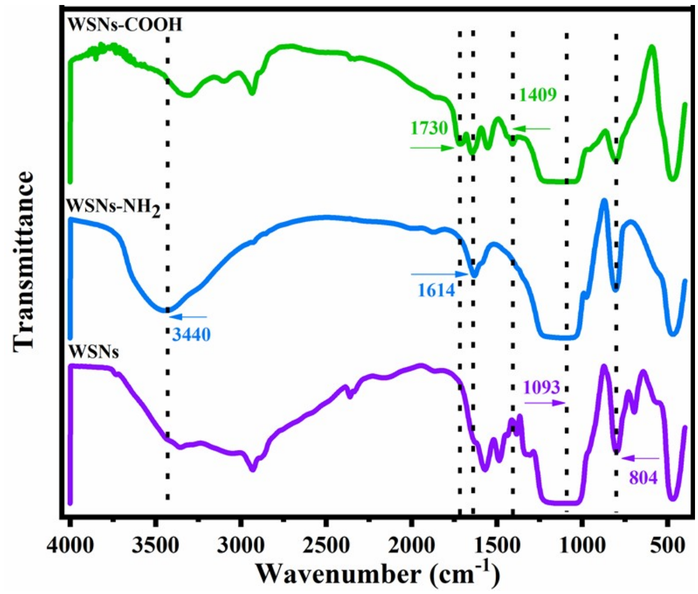

Figure S2 FTIR spectra of WSNs, $WSNs-NH_2$ and WSNs-COOH

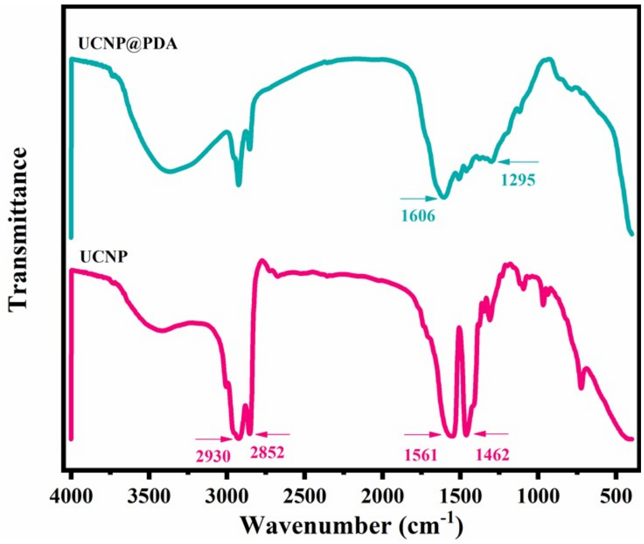

Figure S3 FTIR spectra of UCNP (red line) and UCNP@PDA (cyan line)

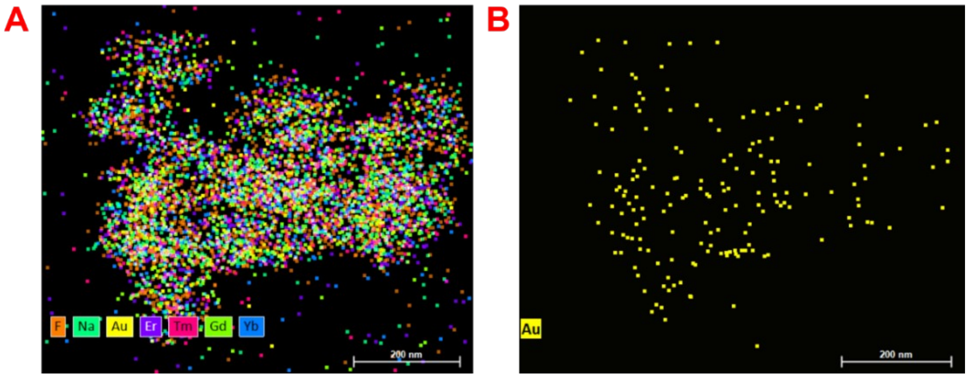

Figure S4 EDS spectrum of UP/Au

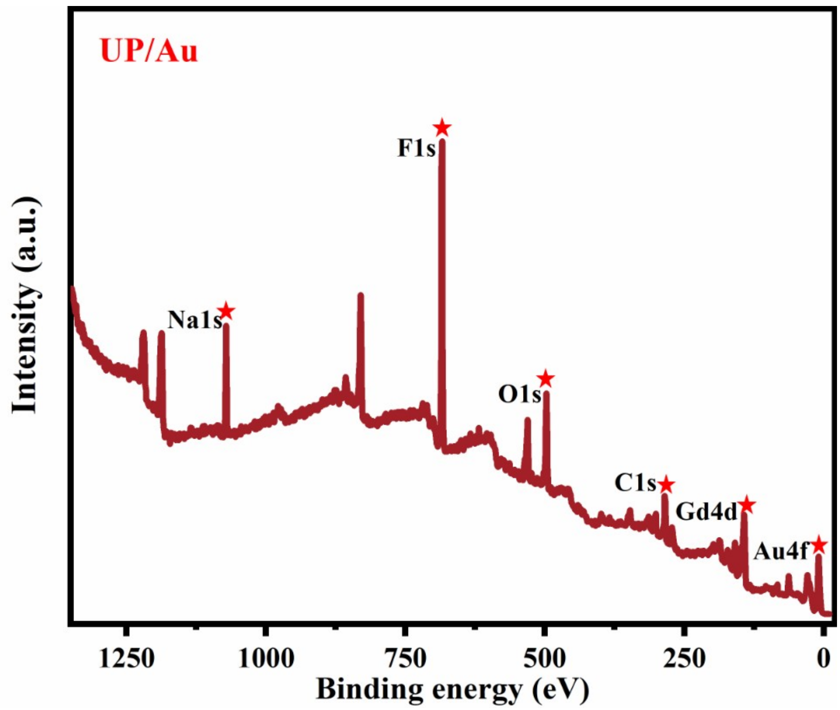

Figure S5 XPS spectrum of UP/Au

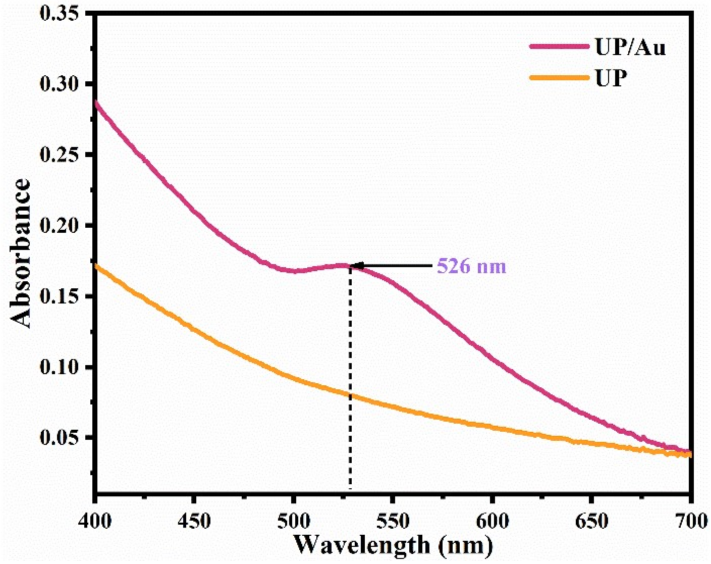

Figure S6 UV-vis spectra of UP before and after AuNP loading

A detailed analysis of the energy transfer existing in $NaErF_4$:0.5%Tm@$NaGdF_4$:40%Yb UCNPs reveals that the photon population of the $^4I_{11/2}$ energy state of a given Er^{3+} can be achieved through direct excitation ($^4I_{15/2}$→$^4I_{11/2}$) or energy transfer from the $^4I_{11/2}$ energy state of adjacent Er^{3+} ions. The energy value of the $^3H_5$ energy state of Tm^{3+} is slightly lower than that of the $^4I_{11/2}$ energy state of Er^{3+}, enabling the $^3H_5$ energy state of Tm^{3+} to capture the energy of the $^4I_{11/2}$ energy state of Er^{3+} and undergo an energy transfer process of $^4I_{11/2}$ (Er^{3+}) →^{3}H5 (Tm^{3+}), thereby reducing the migration of Er^{3+} energy to surface defects. Subsequently, reverse energy transfer (EBT) occurs from the ^{3}H5 energy state of Tm^{3+} to the $^4I_{13/2}$ energy state of Er^{3+}, leading to an electron transition to the $^4F_{9/2}$ state and then back to the ground state, enhancing the red upconversion emission. The Yb^{3+} ions doped in the shell can absorb photons and transition from the $^4F_{7/2}$ to the $^4F1_{5/2}$ energy state and then perform two consecutive energy transfers to Er^{3+} ($^4I_{11/2}$ and $^4F_{7/2}$), thereby enhancing the radiative electron transition of Er^{3+} and promoting red and green light emission. The $^2F_{15/2}$ energy level of Yb^{3+} is almost at the same level as the $^4I_{11/2}$ energy level of Er^{3+}. After Yb^{3+} absorbs photons and reaches the $^4F_{15/2}$ energy state, it preferentially transfers energy to the $^4I_{11/2}$ energy level of Er^{3+} (mainly Er^{3+} at the core-shell interface).A part of the energy released by Er^{3+} in the $^4I_{11/2}$ excited state is captured by the $^3H_5$ energy state of Tm^{3+}, and then a BET process of Tm^{3+} ($^3H_5$)→Er^{3+} ($^4I_{13/2}$) occurs, exciting Er^{3+} to transition to the $^4F_{9/2}$ energy state. The result reveal that UCNP has bright red fluorescence at 655 nm.

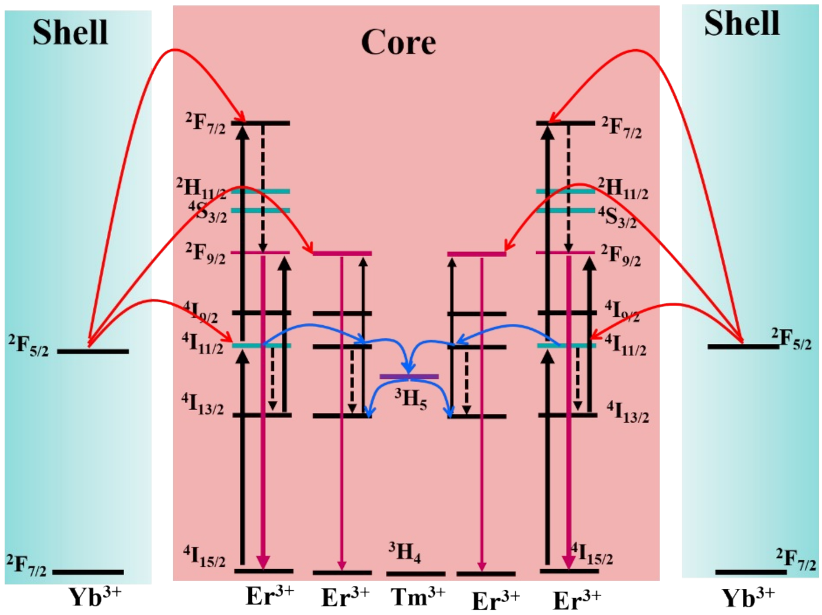

Figure S7 Schematic diagram of energy transfer inside the core-shell UCNPs (black solid arrows, red arrows, blue arrows, and wine red arrows represent photon excitation, energy transfer, and radiation emission, respectively)

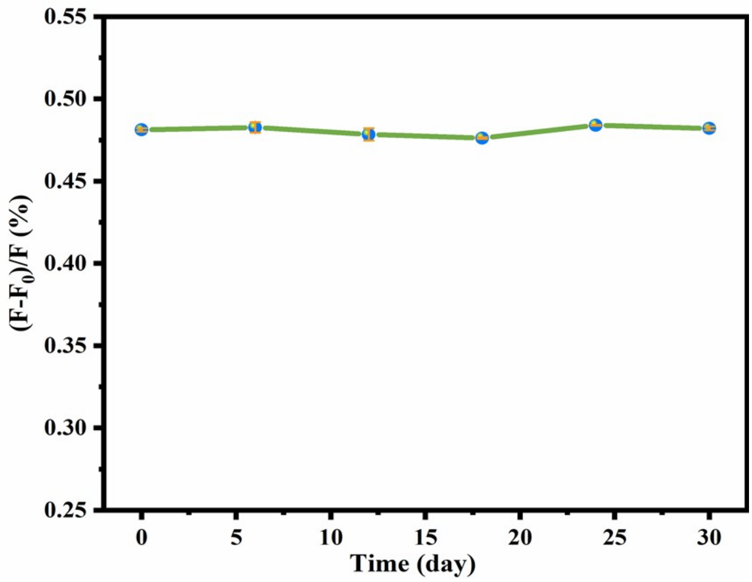

Figure S8 Stability of UP/Au-ssDNA2. The quenching efficiency was calculated via the formula $(F-F_0)/F$, where F_0 and F represent the fluorescence values of the system before and after ssDNA2 was added, respectively.