Carbon dot-mediated synthesis of $NaYF_4:Yb^{3+},Er^{3+}$@carbon dot composites with enhanced upconversion luminescence for temperature sensing

(supporting information)

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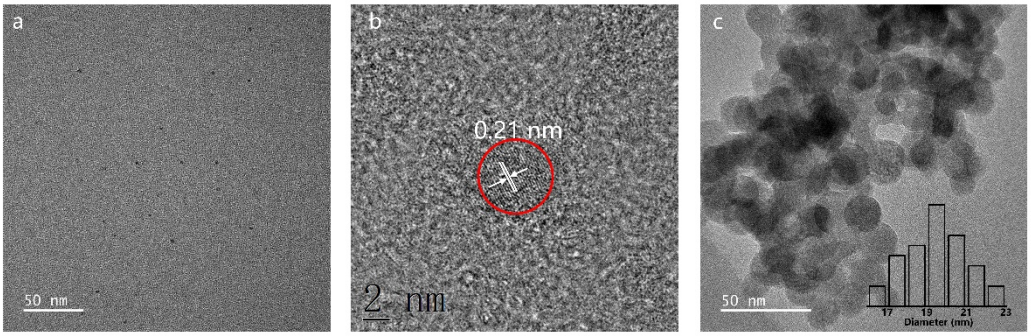

Figure S1. a) TEM and b) HRTEM images of CDs and c) α-$NaYF_4$:18%Yb^{3+},2%Er^{3+} nanoparticles. The inset showing the size distribution of α-$NaYF_4$:18%Yb^{3+},2%Er^{3+} nanoparticles.

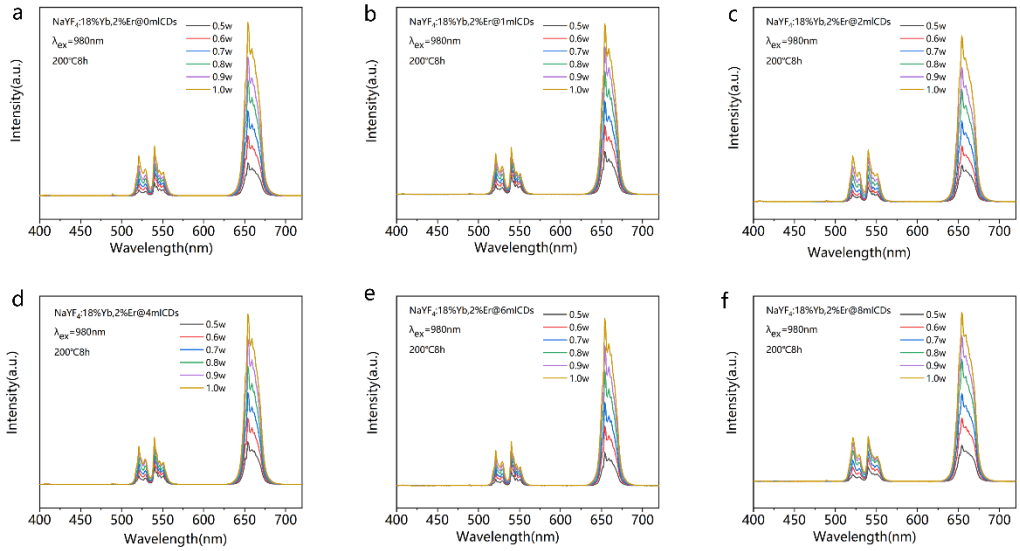

Figure S2. UC emission spectra of β-$NaYF_4$:18%Yb^{3+},2%Er^{3+}@CDs composites (obtained at 200 ℃ for 8 h) under various excitation power.

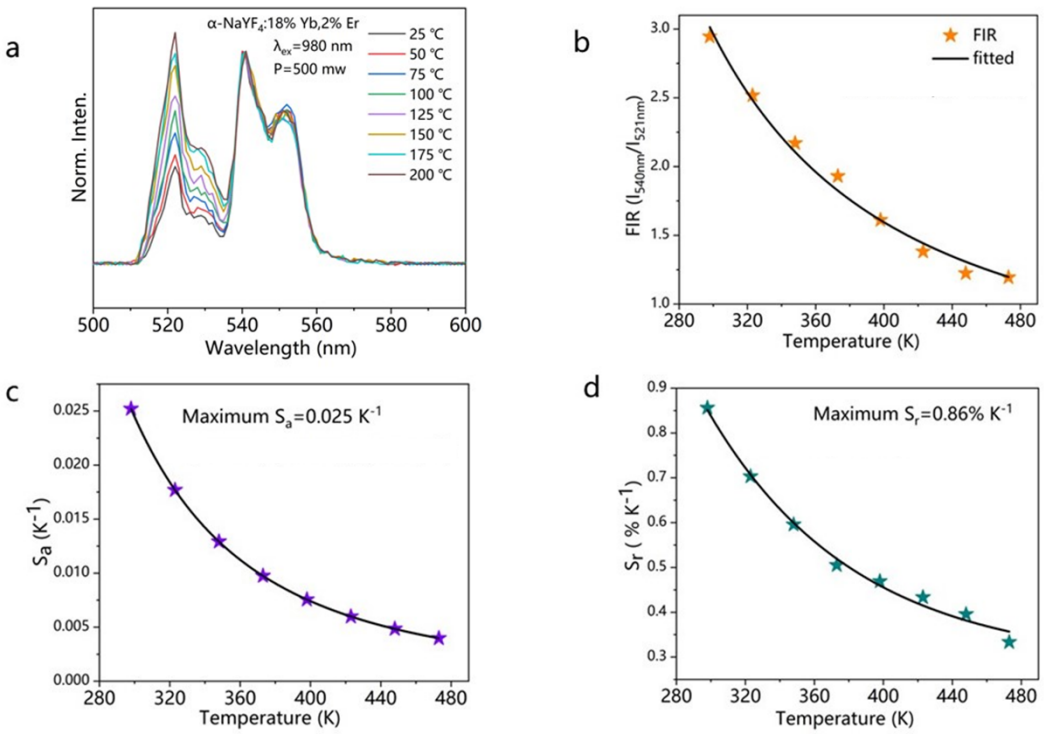

Figure S3. (a) The normalized UC emission spectra as a function of temperature for *α*-$NaYF_4$:18%Yb^{3+},2%Er^{3+} nanoparticles; (b-d) the parameters of *FIR*, S_a, and S_r as functions of temperature.

For the β-NYF@6CDs composite, the *FIR*, S_a, and S_r versus temperature are obtained through fitting as follows:

$$FIR = 0.12\exp(959.55/T) \tag{S1}$$

$$S_a = \frac{115.15}{T^2}\exp(959.55/T) \tag{S2}$$

$$S_r = \frac{959.55}{T^2} \tag{S3}$$

For the α-$NaYF_4$:18%Yb^{3+},2%Er^{3+} NPs, the *FIR*, S_a, and S_r versus temperature are obtained through fitting as follows:

$$FIR = 0.25\exp(743.03/T) \tag{S4}$$

$$S_a = \frac{185.76}{T^2}\exp(959.55/T) \tag{S5}$$

$$S_r = \frac{743.03}{T^2} \tag{S6}$$

Temperature uncertainty (δT) is a critical parameter for optical temperature sensing. The expression can be defined as:

$$\delta T = \frac{1}{S_r}\frac{\delta FIR}{FIR} \tag{S7}$$

where δFIR is the uncertainty of the determined FIR value. It can be computed by the following formula:

$$\frac{\delta FIR}{FIR} = \sqrt{(\frac{\delta I_H}{I_H})^2 + (\frac{\delta I_S}{I_S})^2} \tag{S8}$$

where δI_H and δI_S are the errors in the integrated area of the I_H and I_S transitions estimated dividing the readout fluctuations of the baseline by the maximum intensity value. The resulting signal-to-noise value is $\delta FIR/FIR$=0.41%. Fig. S4 displays the values of δT calculated by Eq. S1 with respect to temperature from 298 K to 473 K.

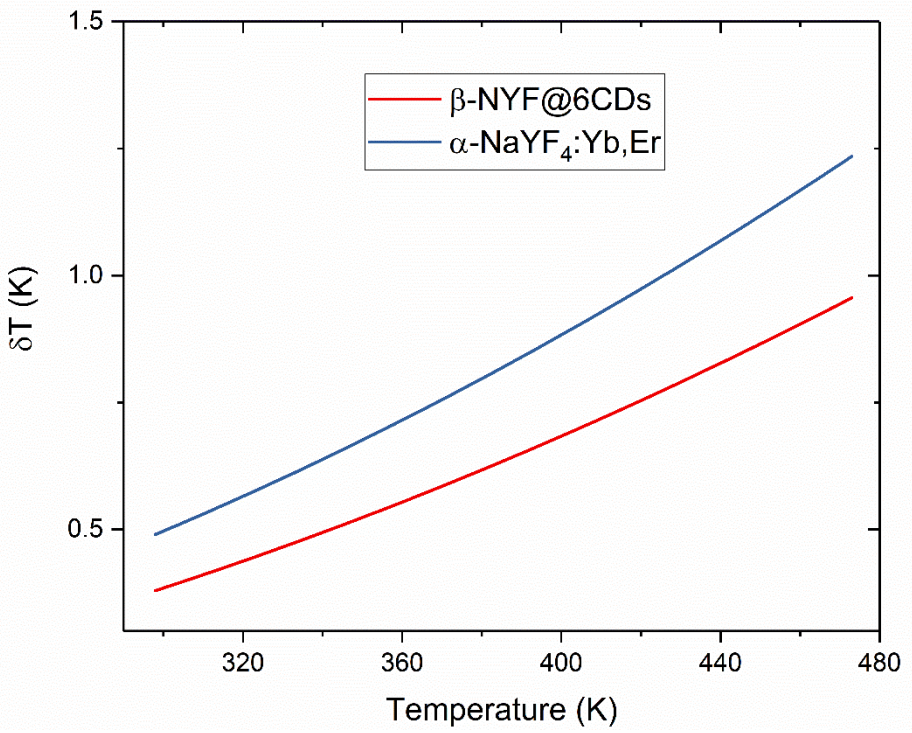

Figure S4. Corresponding temperature uncertainties of the β-NYF@6CDs composite and α-$NaYF_4$:18%Yb^{3+},2%Er^{3+} nanoparticles.