Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.


# Supporting Information

## High-performance upconversion luminescent waveguide using a Rare-earth doped microtube with beveled ends

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**Supporting Information - 1:**

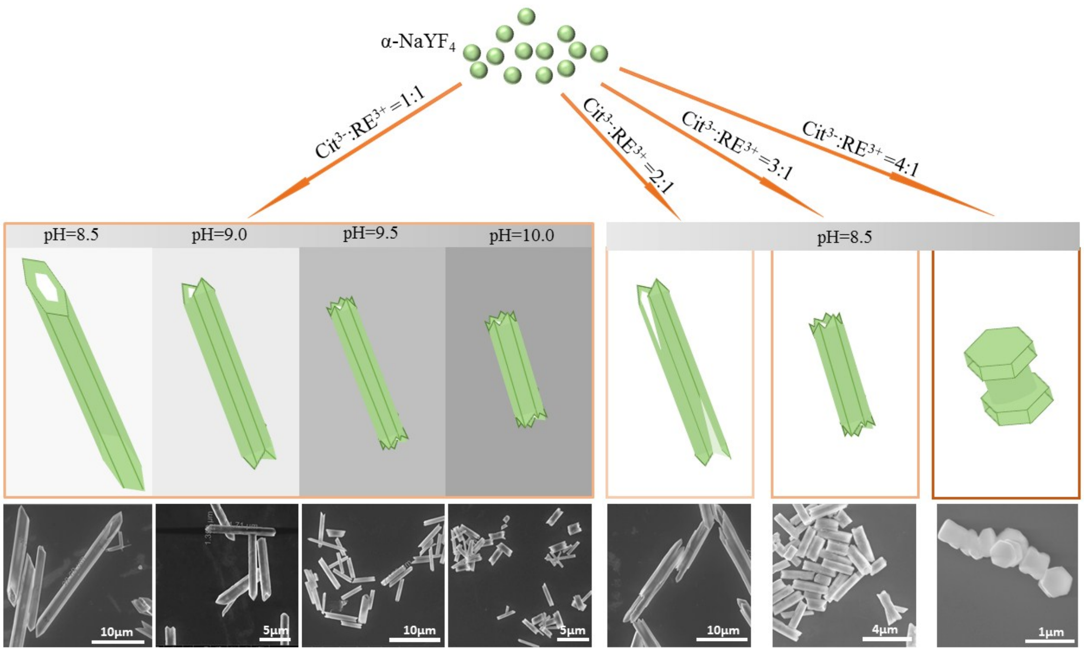


**Figure S1.** Schematic illustration for the possible formation processes of β-$NaYF_4$ microcrystals with various morphologies under different experimental conditions.

**Supporting Information - 2:**

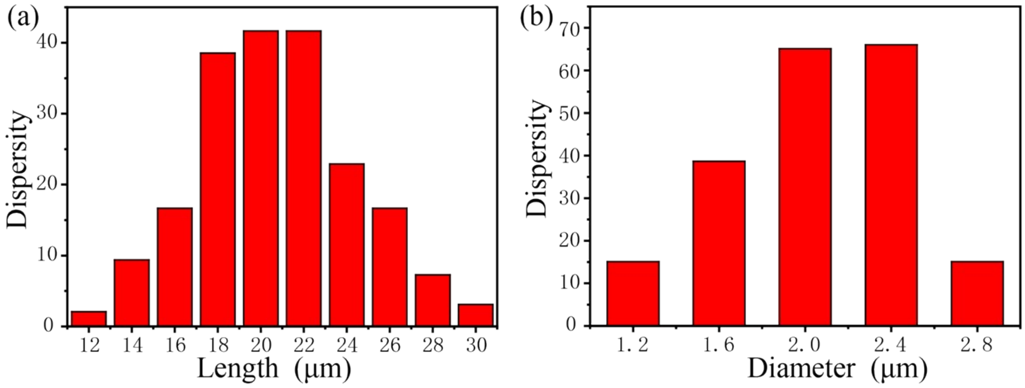


**Figure S2.** The length (a) and diameter (b) dispersity of rare earth doped microtubes with beveled ends.

**Supporting Information - 3:**

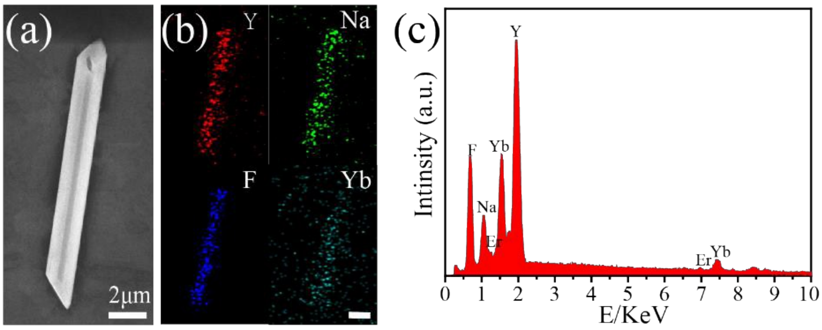


**Figure S3.** SEM (a) and energy-dispersive X-ray maps (b) and spectroscopy (c) of single microtube with beveled ends.

**Supporting Information - 4:**

The near-end excitation is shown in figure S4, and the position scanning video of optical image are shown in supporting video, including experiment (SI-video1) and simulation (SI-video2).

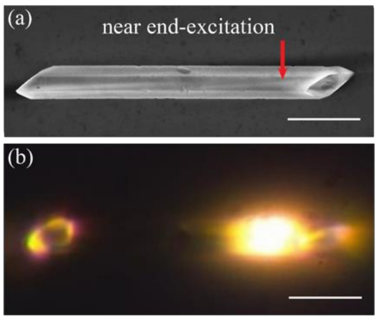


**Figure S4.** SEM (a) and optical images (b) of single beveled-ends microtube. The excited position in the optical image is marked with a red arrow in (a).

**Supporting Information - 5: The calculated method of coupling efficiency**

Due to an objective of NA=0.9 is used to collect the optical signals, the maximum collection angles of φ and θ are 360° and 64°, respectively. According the emission angles of beveled end, around two-thirds of the real-emission intensity at beveled end can be collected in the experiment, and around one-thirds of the real emission intensity at the tube wall can be collected in the experiment.

**(i) For middle-excitation mode**, since only the fluorescence signals transmit along the tube and emit at the beveled ends, the total real-emission intensity of excitation spot C ($I_{total}$) includes three parts: real-emission at C ($I_{Creal}$), real-emission at D ($I_{Dreal}$) and E ($I_{Ereal}$). Therefore, the fluorescence coupling efficiency of middle-excitation mode can be written as,

$$\alpha = \frac{I_{Dreal} + I_{Ereal}}{I_{total}} = \frac{\frac{3}{2}I_D + \frac{3}{2}I_E}{3I_C + \frac{3}{2}I_D + \frac{3}{2}I_E} = \frac{I_D + I_E}{2I_C + I_D + I_E} \tag{1}$$

For the optimized luminescent waveguide used in Figure 6, $I_E$=$I_E$. So, the $\alpha$ can be written as,

$$\alpha = \frac{I_D}{I_C + I_D} \tag{2}$$

According the experiment results of emission intensity, the coupling efficiency of ~15% and ~22% can be calculated for red and green fluorescence, respectively.

**(ii) For end-excitation mode**, since the laser and fluorescence signals simultaneously transmit along the microtube, the observed emission intensity at output end ($I_B$) includes two parts,

$$I_B = I_{B'} + I_{B''} \tag{3}$$

where $I_{B'}$ is the fluorescence intensity transmitted from input end, and $I_{B''}$ is the fluorescence intensity excited by the transmitted laser. Due to the laser can not only excited fluorescence at spot A, but also transmit along the tube to excite the wall ($I_W$) and output end, the laser coupling efficiency of end-excitation mode can be written as,

$$\beta = \frac{\frac{3}{2}I_{B''} + 3I_W}{\frac{3}{2}I_{B''} + 3I_W + \frac{3}{2}I_A} \tag{4}$$

where $I_{B''} = I_B - I_{B'}$, and $I_{B'}$ can be written as,

$$I_{B'} = \frac{\alpha}{1 - \alpha}I_A \tag{5}$$

So, the $\beta$ can be written as,

$$\beta = \frac{(1 - \alpha)I_B - \alpha I_A + 2(1 - \alpha)I_W}{(1 - \alpha)I_B + (1 - 2\alpha)I_A + 2(1 - \alpha)I_W} \tag{6}$$

According the experiment results of emission intensity, the laser coupling efficiency of

~68% can be calculated for end excitation.