Fabrication of long-lived afterglow composites of sulfur nanodots through melt-injection reaction

Ran Li, [a] Sihang Huang, [a] Yongqing Zhai, [b,*] Zhenguang Wang [a,*]

[a] Hebei Technology Innovation Center for Energy Conversion Materials and Devices, Hebei Key Laboratory of Inorganic Nanomaterials, Engineering Research Center of Thin Film Solar Cell Materials and Devices, College of Chemistry and Material Science, Hebei Normal University, No. 20Rd. East of 2nd Ring South, Yuhua District, Shijiazhuang, Hebei 050024, PR China, E-mail: zgwang@hbu.edu.cn

[b] College of Chemistry and Materials Science, Hebei University, No. 180 Rd. East Wusi, Baoding, Hebei, 071002, PR China

Experimental Section

Materials

Sublimed sulfur powder was purchased from Kermel (Tianjin). Polyethylene glycol (M_n = 200), urea, and polyformaldehyde were purchased from Aladdin. Hydrogen peroxide (30%) was purchased from Tianjin Damao Chemical Reagent Factory. Sodium hydroxide (99%) was purchased from Innochem.

Characterization

Prompt and delayed PL spectra of the sample were recorded on a Hitachi F-7000 spectrometer. Temperature dependent prompt and delayed PL spectra, as well as time-resolved decay curves, of the samples were recorded on a Horiba Fluoromax$^+$ spectrometer. Time resolved decay curves were recorded on an Edinburgh FS-5 fluorescence spectrophotometer equipped with a xenon arc lamp (Xe900) and EPL lasers of 375 nm. UV-visible spectra were measured on Shimadzu UV-3600. Transmission electron microscopy (TEM) images were obtained using a transmission electron microscope (FEI-TALOS-F2000X, USA). Powder X-ray diffraction (XRD) patterns were measured using a Bruker D8 Advance diffractometer (Cu K α: λ=1.5405 Å) under ambient conditions. X-ray electron spectroscopy (XPS) spectra were record on Thermo Scientific Escalab 250xi. Fourier transform infrared (FTIR) spectra were obtained on Thermo Fisher Nicolet iS10.

Synthesis of S-dots: S-dots were synthesized by a H_2O_2 etching method. Distilled water (50 ml), sublimed sulfur (1.4 g), PEG-200 (3ml) and NaOH (4.0 g) were added into a three-necked round-bottomed flask and react at 90 ℃ for 72 h. The products were treated with 5.5% hydrogen peroxide, and freeze-dried into powder for subsequent use.

Synthesis of UF@S-dots: Urea (2 g) was added into a three-necked round-bottomed flask, followed by heating at 150 ℃ until melting. Paraformaldehyde (1.5 g) was injected into melt urea, which was allowed to react for 30 min. The as-obtained powder was heated at 150 ℃ for 1 h.

Figures

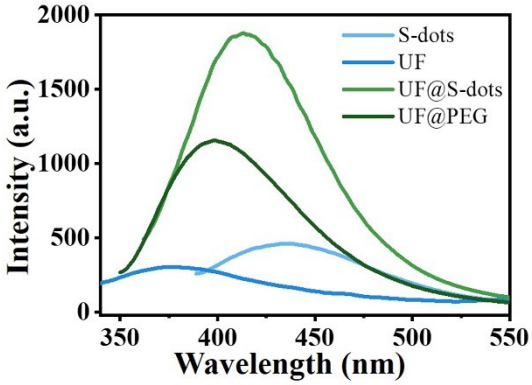

Figure S1. Prompt PL spectra of S-dots, UF and UF@PEG, UF@S-dots.

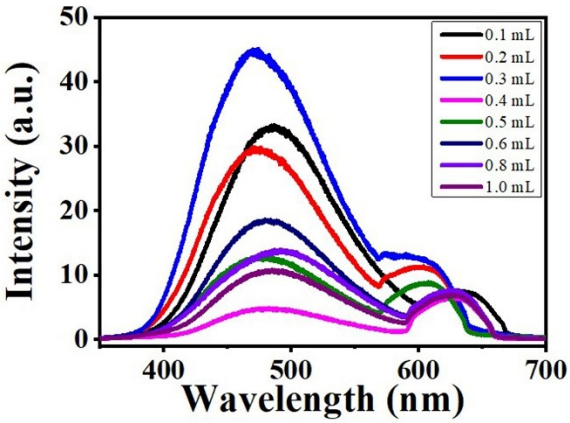

Figure S2. Delayed (right) PL spectra of composites produced by loading different amount of PEG into the UF matrix.

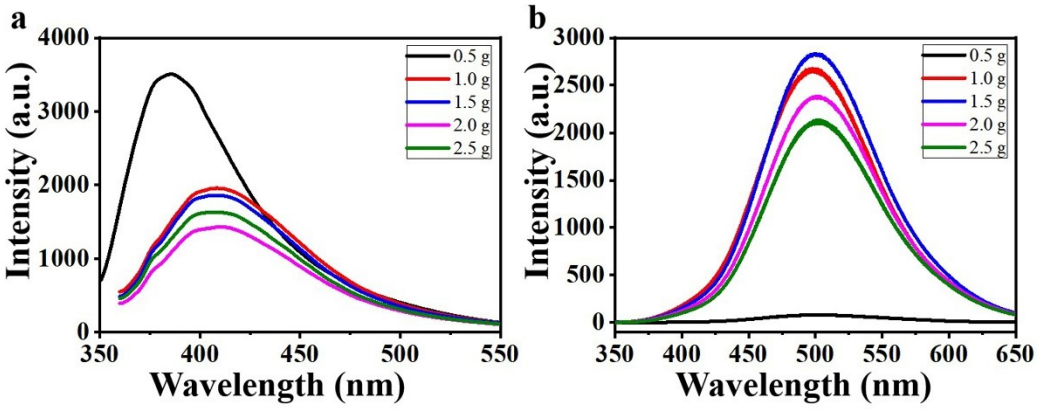

Figure S3. Prompt (a) and delayed (b) PL spectra of UF@S-dots produced by adding different amounts of paraformaldehyde.

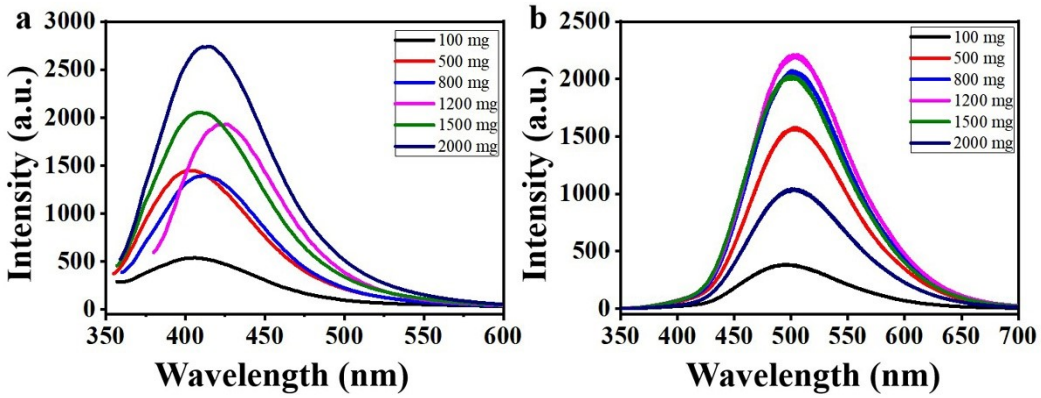

Figure S4. Prompt (a) and delayed (b) PL spectra of UF@S-dots, produced by loading different amount of S-dots.

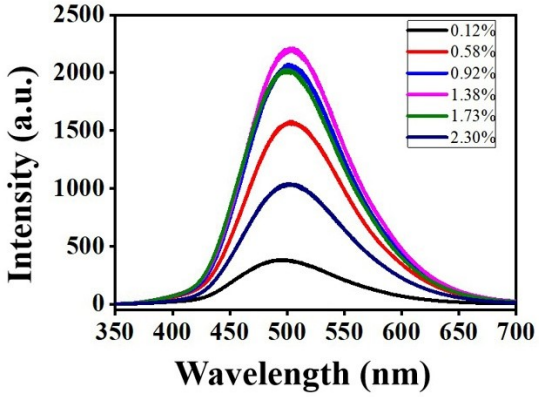

Figure S5. Delayed PL spectra of composites with different content of sulfur.

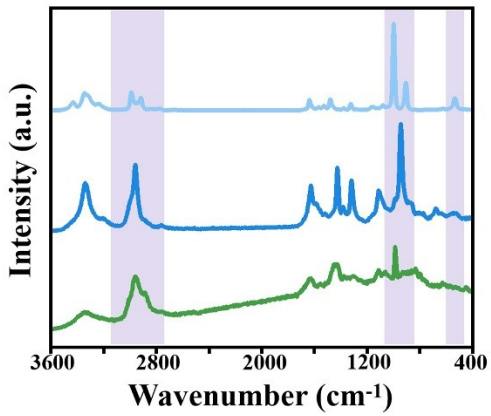

Figure S6. Raman spectra of paraformaldehyde and urea before (light cyan color) and

after (dark cyan color) reaction, and UF@S-dots (green color).

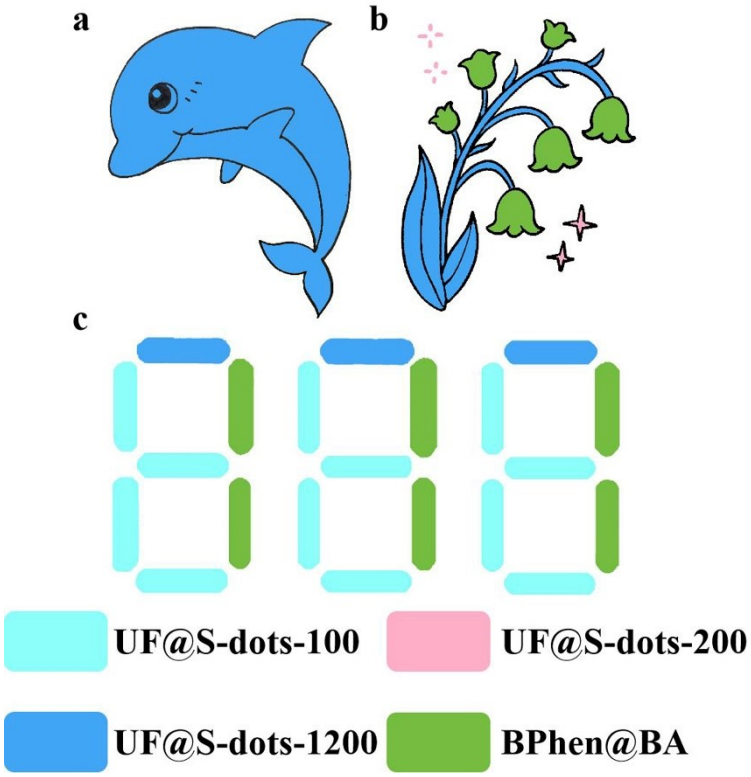

Figure S7. The filling information of each part of the application patterns.

Tables

Table S1. The emission decay data from the prompt and delayed emission of UF@S-dots were fitted using a two-exponential function, yielding emission lifetimes ($\tau_{1\text{-}2}$) and emission intensity fractions ($f_{1\text{-}2}$, %). Based on these values, the average emission lifetime τ_{avg} (ns or s)was calculated.

Category	τ_1	f_1	τ_2	f_2	τ_{avg}
Prompt	4.28 ns	69.6	1.35 ns	30.4	3.39 ns
Delayed	0.14 s	36.8	1.28 s	63.2	0.86 s

Table S2. The experimental emission decay data of UF@S-dots at different test temperatures were fitted using a two-exponential function, yielding emission lifetimes ($\tau_{1\text{-}2}$, s) and emission intensity fractions ($f_{1\text{-}2}$, %). Based on these values, the average emission lifetime τ_{avg} (s) was calculated.

Temperature	τ_1	f_1	τ_2	f_2	τ_{avg}
77K	0.23	35.7	2.26	64.3	1.54
135K	2.14	63.5	0.21	36.5	1.44
185K	2.14	61.5	0.19	38.5	1.39
235K	1.74	62.4	0.14	37.6	1.14
273K	0.14	36.6	1.62	63.4	1.08
298K	0.14	36.8	1.28	63.2	0.86
325K	0.08	45.7	0.54	54.3	0.33