Supporting information

Efficient artificial light-harvesting systems with gel properties formed by ion recognition

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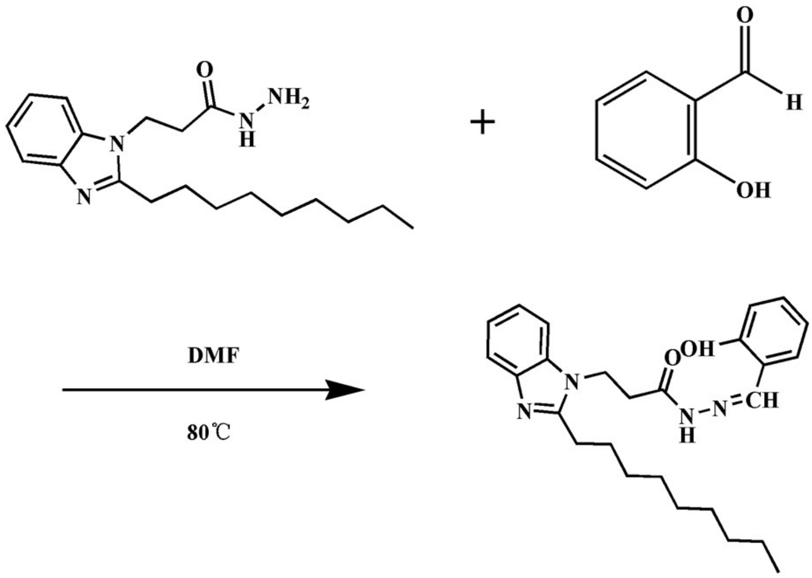
Materials

1. Instrumentation and methods

All reactions were taken place in the air except as otherwise noted. All measurements were carried out at room temperature. All chemicals were used without further purification, unless otherwise noted. 2-(2-nonyl-1H-benzimidazol-1-yl) propanohydrazide salicylaldehyde was purchased from Shanghai Bangcheng Chemical Co. Ltd.. Rhodamine B was purchased from China Pharmaceutical Corporation Beijing Purchasing and Supply Station.

NMR spectra were carried out on a Bruker 400 MHz spectrometer with internal standard tetramethylsilane (TMS) and solvent signals as internal references at room temperature, and the chemical shifts were showed in ppm. The HRMS spectra were carried out on Aglient 6550 of Thermo Fisher-QE. The morphologies of the synthesized samples were characterized with a JSM-6701F SEM using an accelerating voltage of 5kV. The UV-Vis absorption spectra were measured on UV-1750 spectrophotometer. The fluorescence spectra were measured on RF-6000 instrument. The quantum yields were measured on a FLS980 fluorescence spectrometer. X-ray diffraction patterns (XRD) performed with XPert PRO .

2. Synthesis and characterization of gelator G3



Scheme S1. Synthesis of gelator G3

Synthesis of Gelator G3: 2-(2-nonyl-1H-benzimidazol-1-yl) propanohydrazide (8 g, 0.023 mol) was mixed with Salicylaldehyde (2.84 g, 0.023 mol) in DMF solution and was refluxed for 8 h. After the reaction mixture was cooled to room temperature, the mixture was added to distilled water and lots of solid powder was precipitated by filtration. Then the precipitate was filtered and washed with ethyl alcohol, then dried under vacuum to gelator G3. Yield: 9.02g (83%).

^{1}H NMR (400 MHz, DMSO-d_6) δ (ppm): 11.69 (d, J = 5.0 Hz, 1H), 11.33 – 11.13 (m, 1H), 10.10 (d, J = 3.1 Hz, 1H), 8.30 (d, J = 31.2 Hz, 1H), 7.61 – 7.43 (m, 3H), 7.31 – 7.08 (m, 3H), 6.98 – 6.79 (m, 2H), 4.25 (dd, J = 14.4, 7.2 Hz, 2H), 2.92 – 2.79 (m, 2H), 2.69 (dd, J = 17.8, 10.8 Hz, 1H), 2.30 (t, J = 7.0 Hz, 1H), 2.10 – 1.96 (m, 2H), 1.86 – 1.73 (m, 2H), 1.57 – 1.07 (m, 12H), 0.84 (dd, J = 6.5, 4.3 Hz, 3H).

^{13}C NMR (101 MHz, DMSO) δ 173.72 – 173.52 (m), 168.34 (s), 158.03 (s), 156.75 (s), 155.46 (s), 147.03 (s), 142.97 (s), 135.43 (s), 131.64 (s), 129.81 (s), 126.93 (s), 121.88 (s), 119.72 (s), 118.51 (s), 116.79 (s), 110.40 (s), 42.57 (s), 31.76 (s), 30.86 (s), 29.34 (s), 27.53 (s), 26.83 (s), 25.18 (s), 22.56 (s), 14.42 (s). ESI-MS: m/z (L + H) $^{+}$ 448.29.

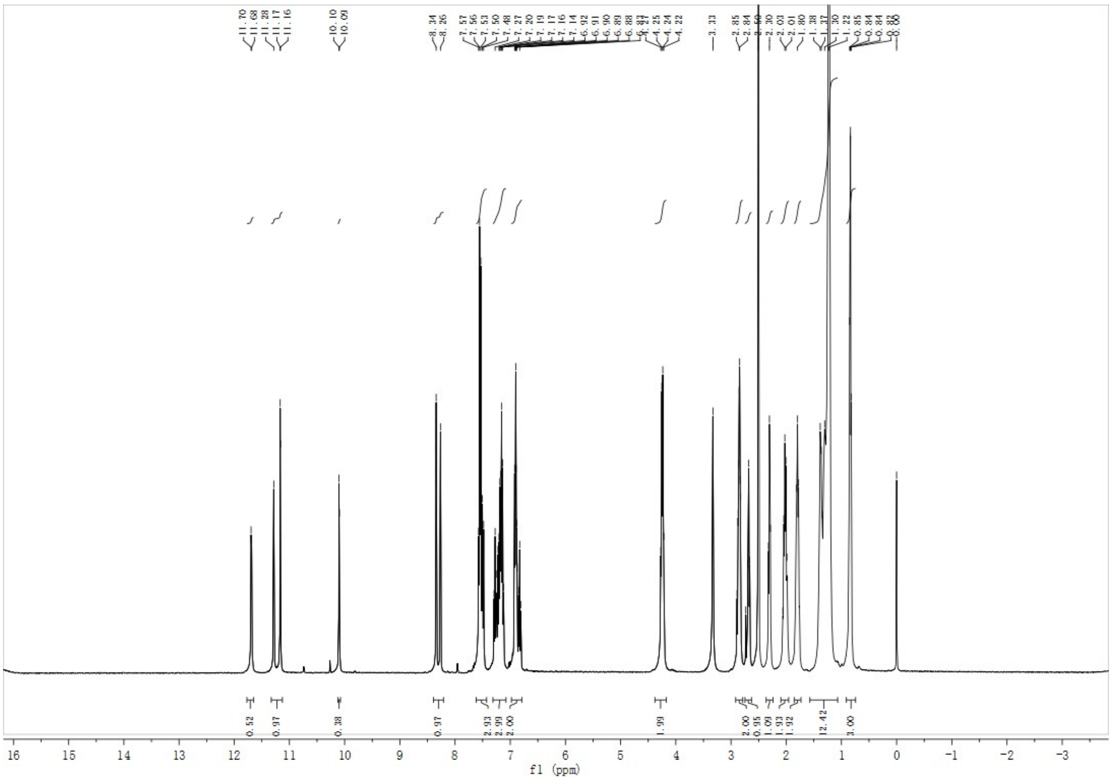


Fig. S1. ^{1}H NMR spectrum of gelator G3

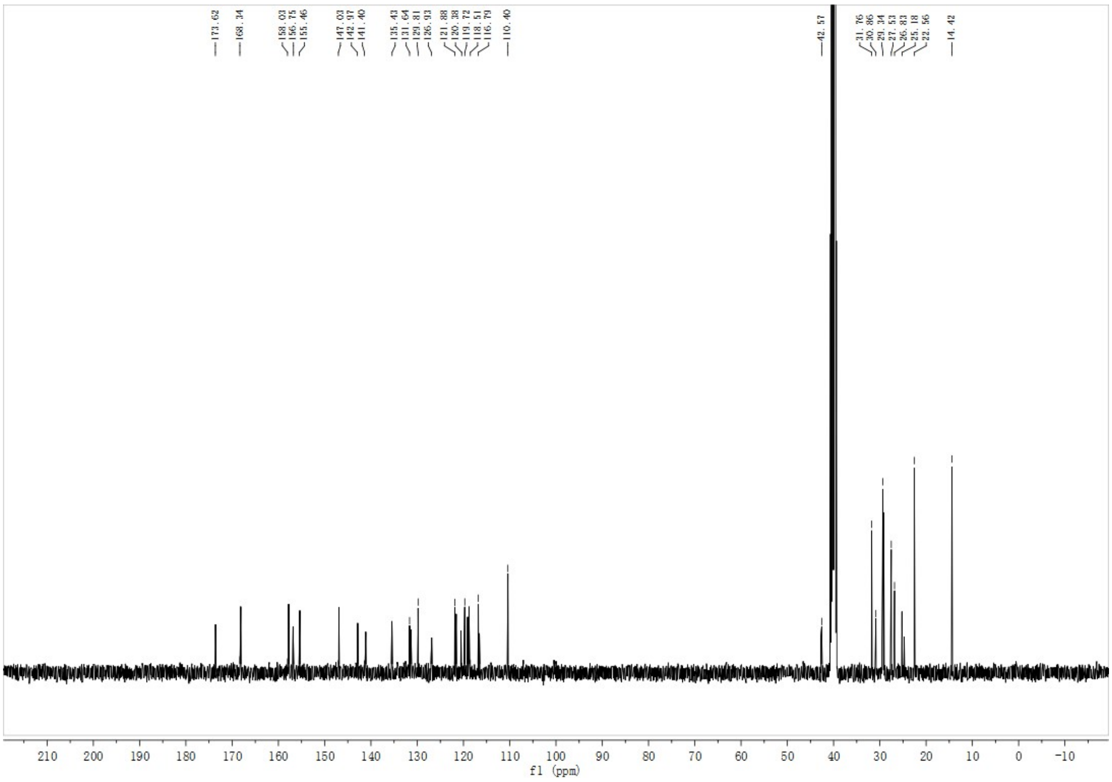


Fig. S2. ^{13}C NMR spectrum of gelator G3

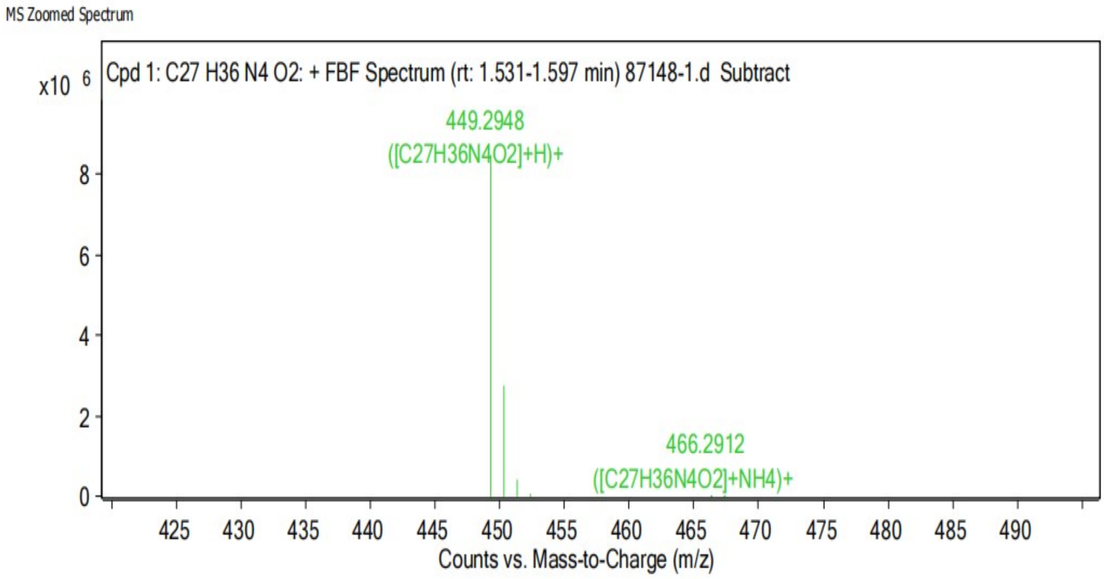


Fig. S3. HRMS spectra of gelator G3

3. FT-IR spectra

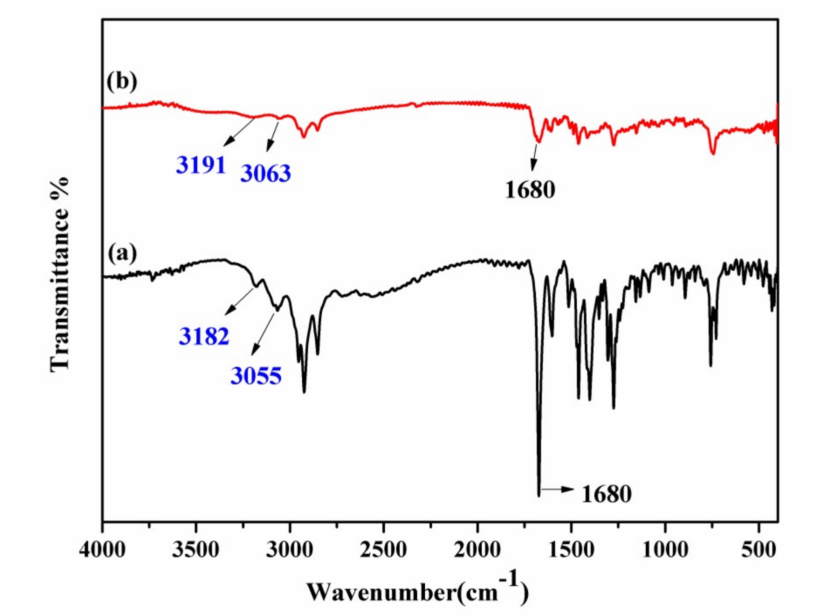


Fig. S4 FT-IR spectra of the gelator G3 (a) and G3-Mg^{2+} complex (b)

4. The figure of mechanism

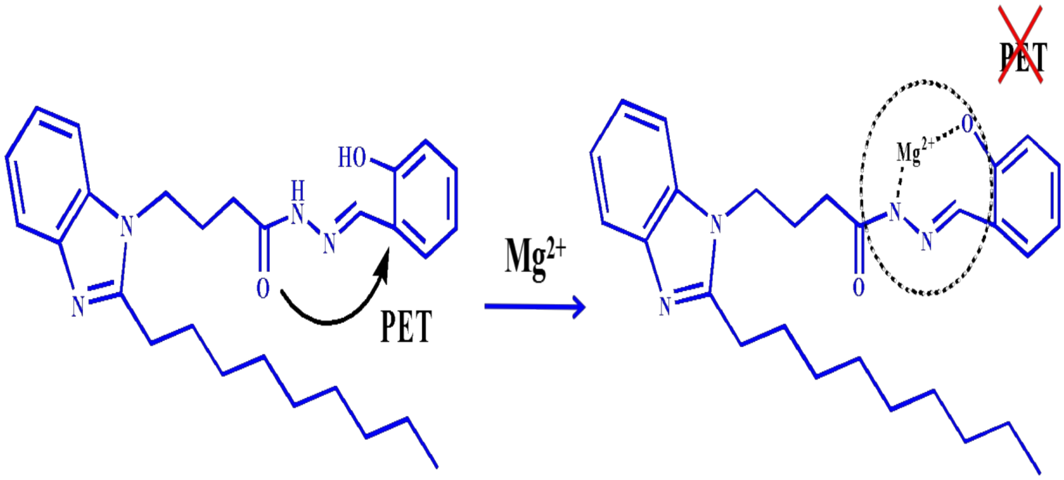


Fig. S5 The possible luminescence mechanism of the G3@Mg-sol

5. XRD

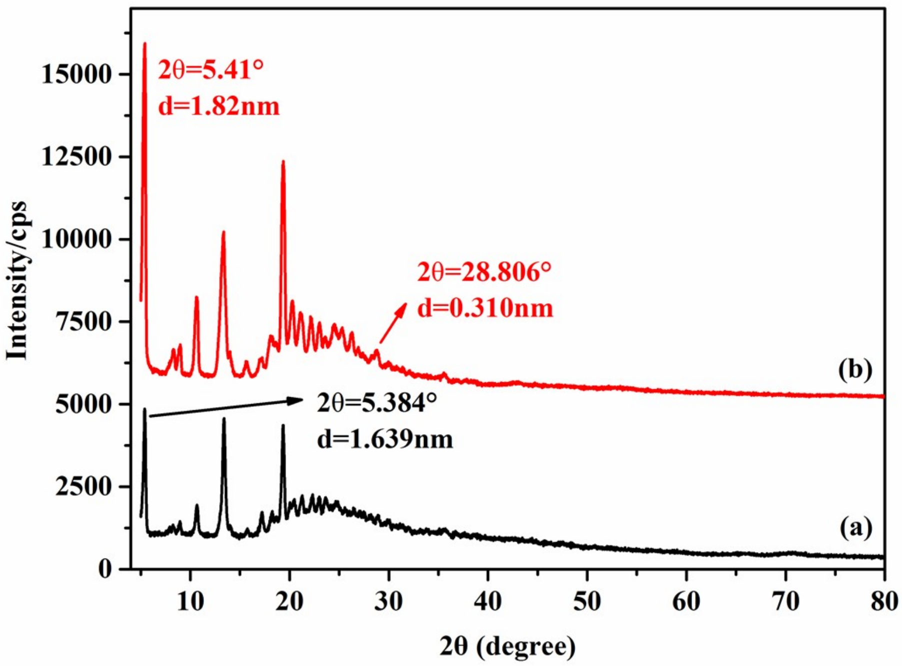


Fig. S6 XRD of the gelator G3 (a) and G3-Mg^{2+} complex (b)

6. Fluorescence lifetime of G3@Mg-sol and G3@Mg-sol/RhB

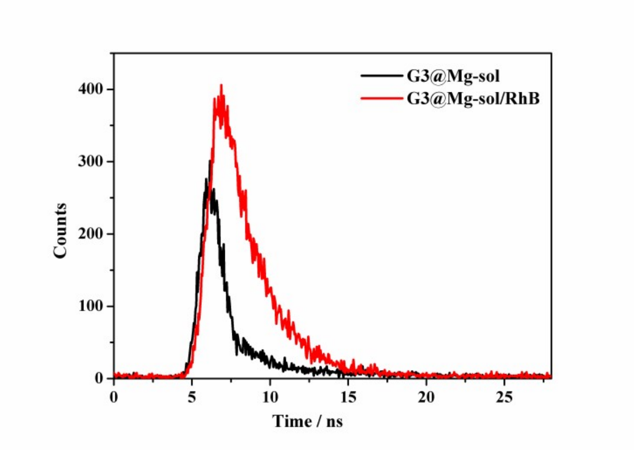


Fig. S7 The fluorescence lifetime of (a) G3@Mg-sol and G3@Mg-sol/RhB

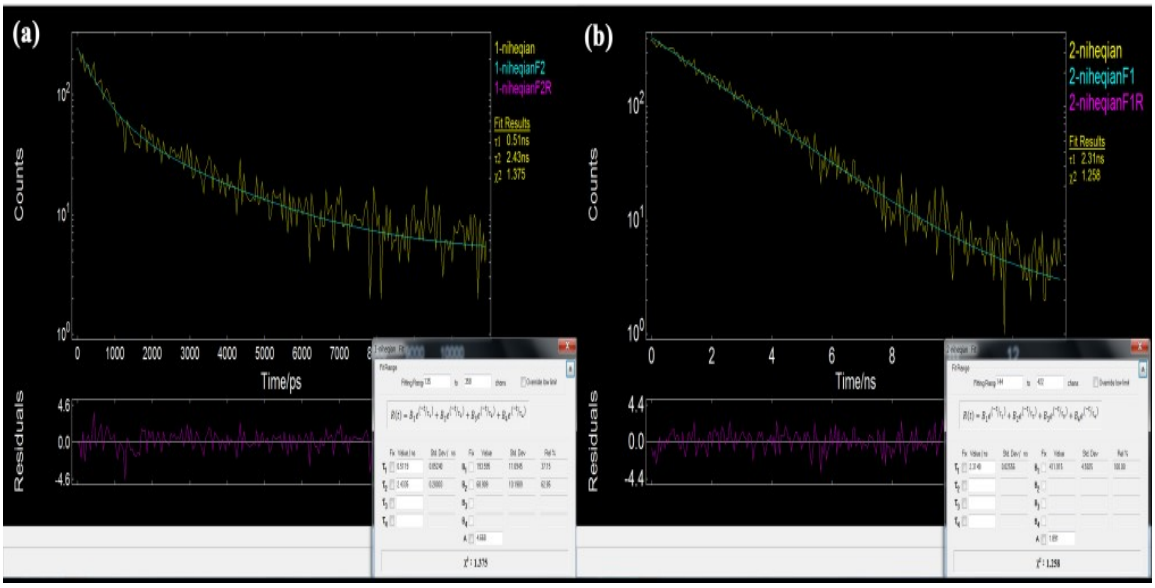


Fig. S8 The fluorescence lifetimes of (a) G3@Mg-sol; (b) G3@Mg-sol/RhB

7. Fluorescence quantum yield of G3@Mg-sol/RhB

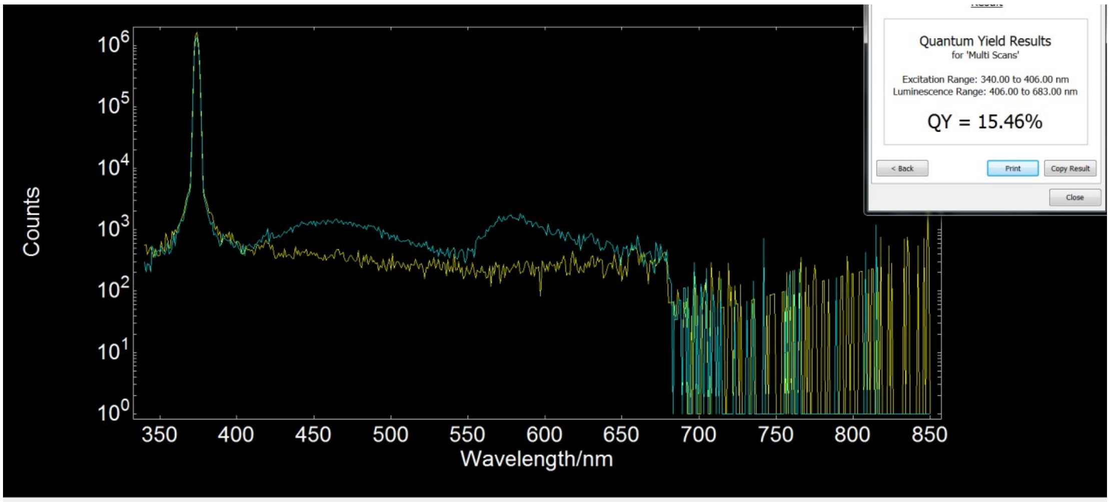


Fig. S9 The fluorescence quantum yield at molar ratio

of the G3@Mg-sol/ RhB was 50:1

8. Energy transfer efficiency (Φ_{ET})

The energy-transfer efficiency (Φ_{ET}) was calculated using the following equation:

$$\Phi_{ET}=1-I_{DA}/I_{D}$$ [1]

Where I_{DA} and I_D are the fluorescence intensities of the emission of G3@Mg-sol/RhB (donor and acceptor) and G3@Mg -sol(donor), respectively when excited at 374nm.

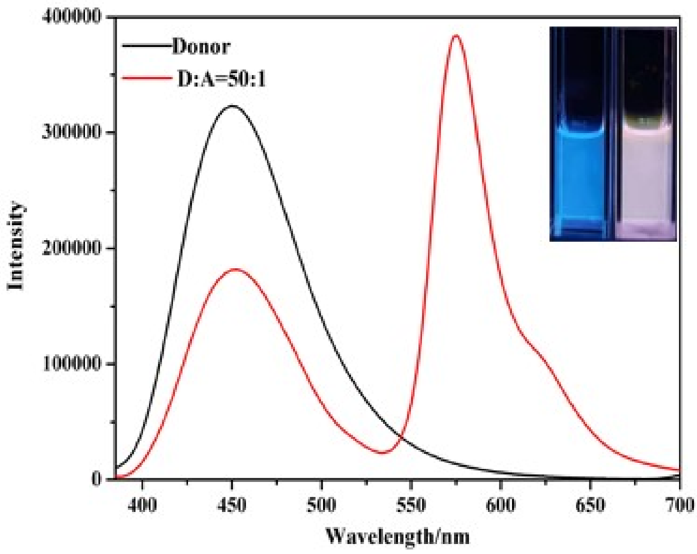


Fig. S10. Fluorescence spectra of G3@Mg-sol and G3@Mg-sol/RhB in ethanol and H_2O (λ_{ex}=374 nm). Inset: photographs of G3@Mg-sol and G3@Mg-sol/RhB under 365 nm UV light (G3@Mg-sol =1μM, RhB= 0.02 μM)

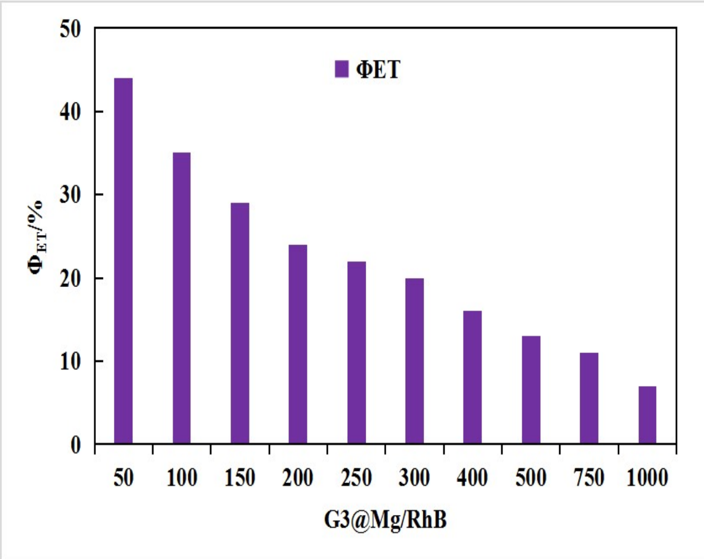


Fig. S11. The energy transfer efficiency of G3@Mg-sol/RhB at different ratios

9. Antenna effect

The antenna effect under certain concentrations of donor and acceptor equals the ratio of the emission of the acceptor upon excitation of the donor.[2]

$$AE=[I_{DA(\lambda ex=donor)} - I_{D(\lambda ex=donor)}] / I_{DA(\lambda ex=acceptor)}$$

Where $I_{DA\ (\lambda ex\ =\ donor)}$ and $I_{DA\ (\lambda ex\ =acceptor)}$ are the fluorescence intensities at 577 nm with excitation of the donor at 374 nm and direct excitation of the acceptor at 440 nm, respectively. $I_{D\ (\lambda ex\ =\ donor)}$ is the fluorescence intensities of the G3@Mg-sol assembly, which was normalized with the G3@Mg-sol/RhB assembly at 440 nm.

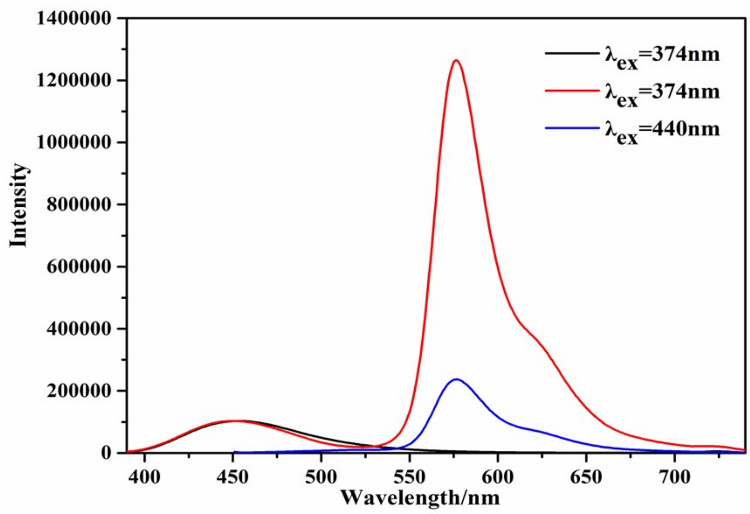


Fig S12. Fluorescence spectra of G3@Mg-sol/RhB (red line), black line (donor emission, λex = 374 nm), blue trace (acceptor emission, λex = 440 nm). The black line represents the fluorescence spectrum of G3@Mg-sol, which was normalized according to the fluorescence intensity at 453 nm of the red line ([G3@Mg-sol] = 1μM, [RhB] = 0.02μM

10. Gelation property of gelator G3

Table S1. Gelation property of gelator G3

Entry	Solvent	State
1	n-Butyl alcohol	P
2	Propyl alcohol	P
3	Ethanediol	G
4	Glycol and water	G
5	Ethyl acetate	P
6	Acetonitrile	P
7	Methanol	PG
8	Clycerol	P
9	Isoamyl alcohol	S
10	Isopropanol	P
11	Dichloromethane	P
12	Ethanol	PG
13	DMF	S
14	DMSO	S
15	Cyclohexane	P
16	Petroleum ether	S
17	Tetrahydrofuran	S
18	Chloroform	S
19	Acetone	S

[a]G, P, S and PG denote gelation, precipitation, solution and part gelation, respectively.

[b]The critical gelation concentration (wt %, 10 mg/mL)

11. The G3-gel

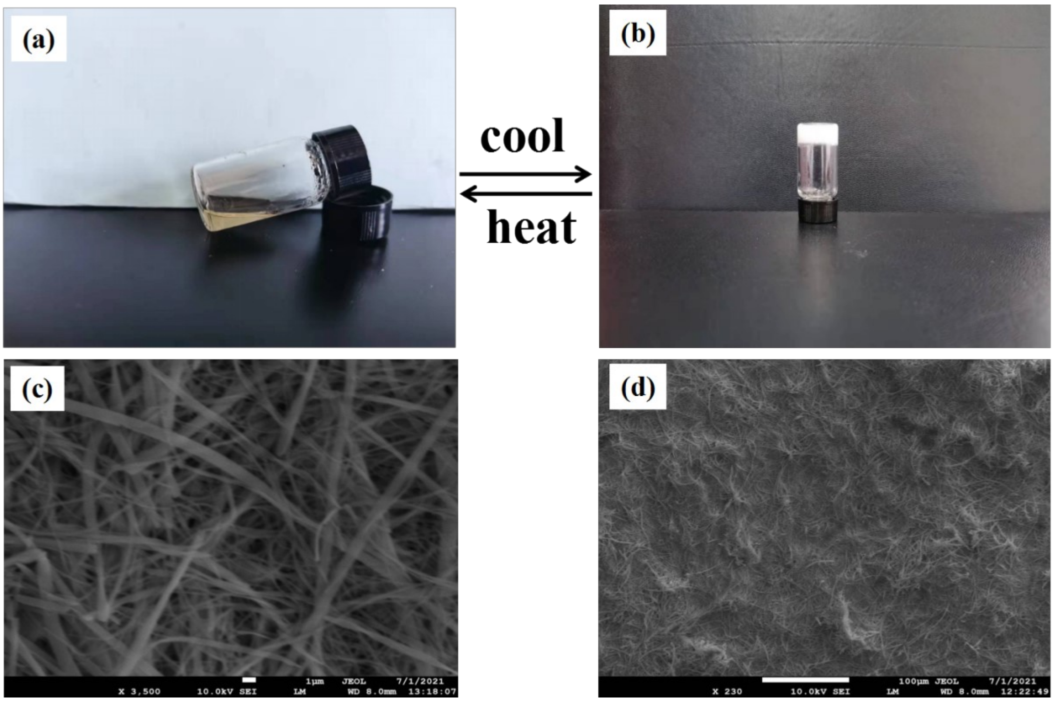


Fig. S13. a,b) the reversible gel-sol transformation of the G3-gel by temperature;

c, d) SEM images of G3-gel in mixed solutions

12. The G3@Mg-sol and G3@Mg-gel

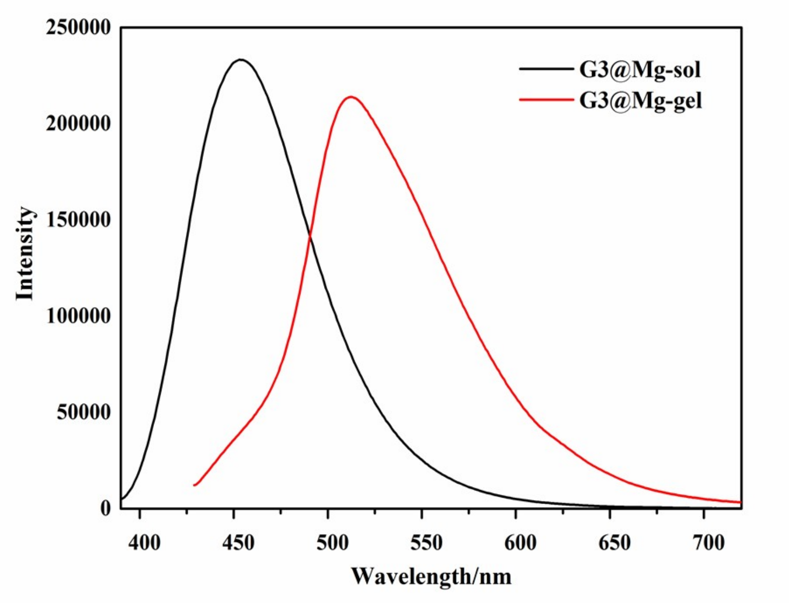


Fig. S14 Emission spectra of G3@Mg-sol and G3@Mg-gel

13. The energy transfer of G3@Mg-gel

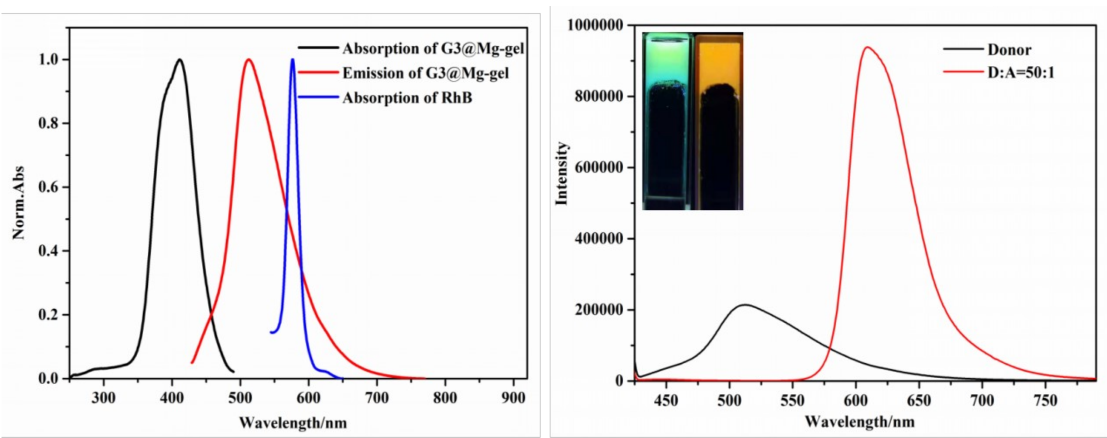


Fig. S15 (a) Normalized absorption and emission spectrum of G3@Mg-gel, absorption spectrum of RhB; (b) Fluorescence spectrum of G3@Mg-gel/RhB ([G3@Mg-gel] = 45μM, [RhB]=0.9μM) in glycol and water with the ratio is 50:1 of G3@Mg-gel/RhB (Inset: photographs of G3@Mg-gel/RhB)

14. The fluorescence lifetimes of G3@Mg-gel and G3@Mg-gel/RhB

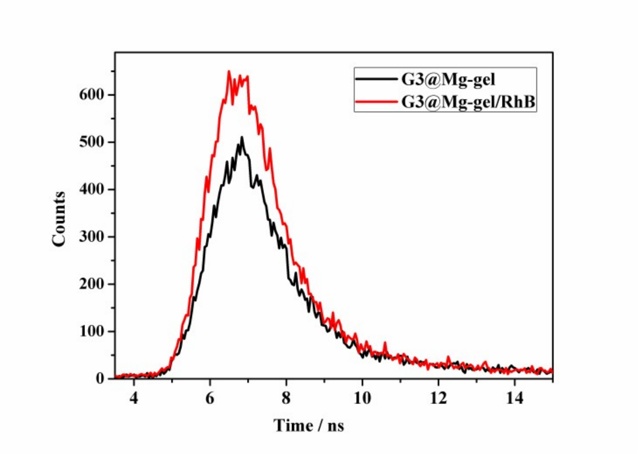


Fig. S16 The fluorescence lifetimes of (a) G3@Mg-gel; (b) G3@Mg-gel/RhB

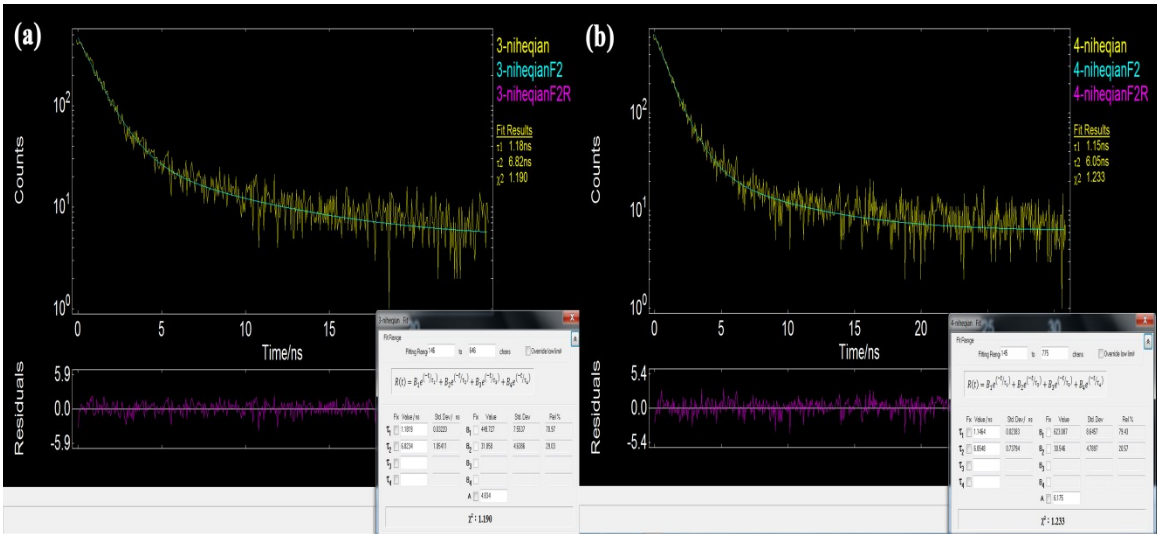


Fig. S17 The fluorescence lifetimes of (a) G3@Mg-gel; (b) G3@Mg-gel/RhB

15. Fluorescence quantum yield of G3@Mg- gel/RhB

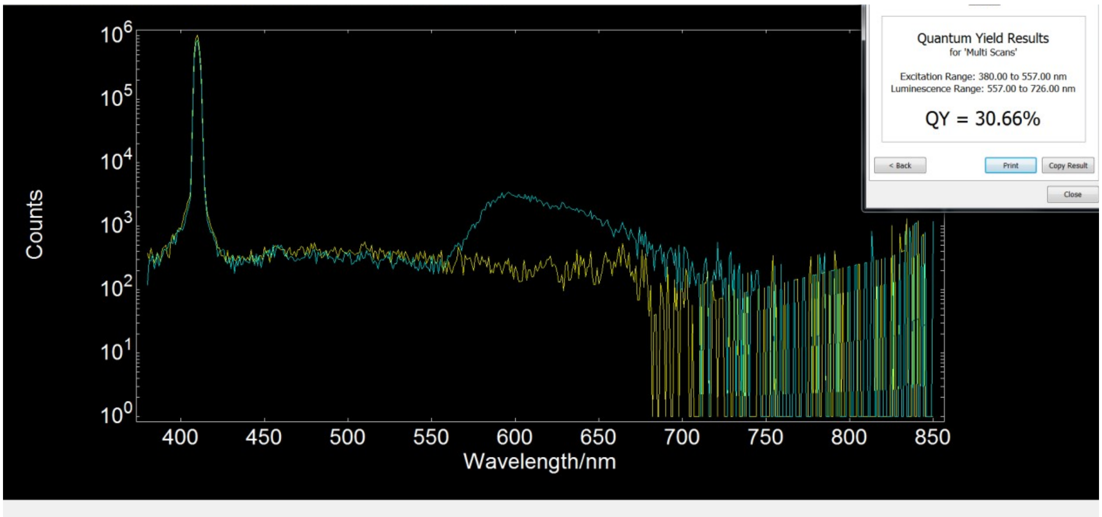


Fig. S18. The fluorescence quantum yield of the G3@Mg-gel/RhB at molar ratio 50:1

Notes and references

1 (a) J. J. Li, H. Y. Zhang, X. Y. Dai, Z. X. Liu and Y. Liu, Chem. Commun., 2020, **56**, 5949-5952; (b) G. P. Sun, W. R. Qian, J. M. Jiao, T. T. Han, Y. K. Shi, X. Y. Hu and L. Y. Wang, J. Mater. Chem. A, 2020, **8**, 9590-9596.

2 (a) J. J. Li, Y. Chen, J. Yu, N. Cheng, Y. Liu, Adv. Mater., 2017, **29**, 1701905; (b) S. Guo, Y. Song, Y. He, X. Y. Hu, L.Wang, Angew. Chem. Int. Ed., 2018, **57**, 3163; (c) M. Hao, G. P. Sun, M. Z. Zuo, Z. Q. Xu, Y. Chen, X. Y. Hu, L. Y. Wang, Angew. Chem. Int. Ed., 2019, **58**, 2.