Electronic Supplementary Information (ESI)

Photocontrolled morphological conversion and chiral transfer of snowflake-like supramolecular assembly based on azobenzene-bridged bis(dibenzo-24-crown-8) and a cholesterol derivative

Hui-Juan Wang,[a] Heng-Yi Zhang,*[a,b] Huang Wu,[a] Xian-Yin Dai,[a] Pei-Yu Li,[a] and Yu Liu*[a,b]

[a] Department of Chemistry, State Key Laboratory of Elemento-Organic Chemistry, (Tianjin), Nankai University, Tianjin 300071, P. R. China

[b] Collaborative Innovation Center of Chemical Science and Engineering (Tianjin) Nankai University, Tianjin 300071 (P. R. China)

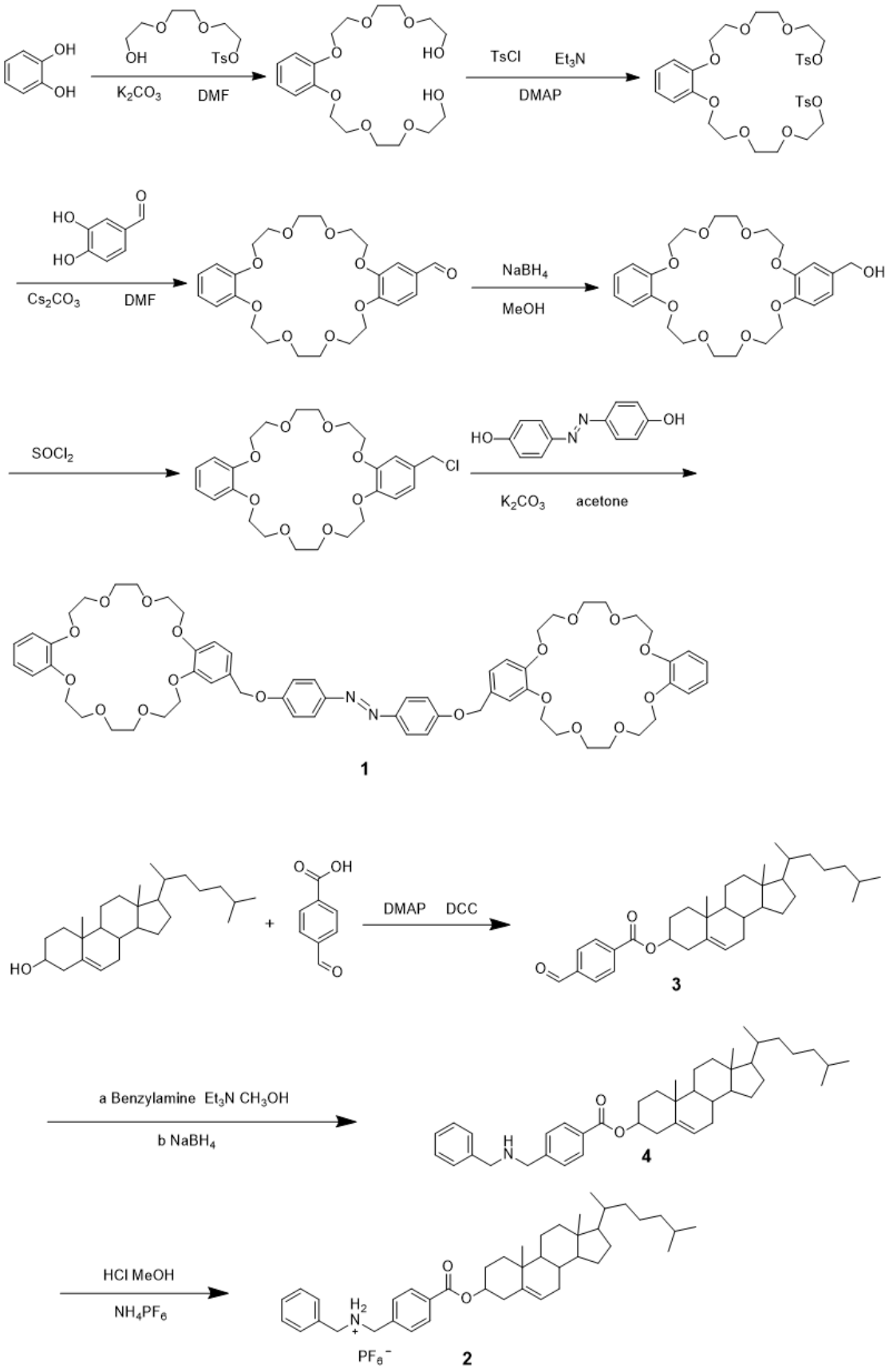
E-mail: hyzhang@nankai.edu.cn, yuliu@nankai.edu.cn

Experimental Section

Instrumentation and methods

All the reagents and solvents were commercially available and used as received without further purification. The precursor 4-chloromethylenedibenzo-24-crown-8 ether was prepared according to literature procedures[1]. Column chromatography was performed on silica gel (200-300 mesh). NMR spectra were recorded on Bruker AV400 instrument at 25 ℃ and chemical shifts were recorded in parts per million (ppm). Electrospray ionization (ESI) mass spectra were measured on a Q-TOF LC-MS. High-resolution matrix-assisted laser desorption/ionization spectra (HR-MALDI) were measured on a Varian 7.0T FT-MS. The UV light irradiation experiment was carried out using a ZF-7A lamp (365 nm, 8 W), and the visible light irradiation experiment ($\lambda > 420$ nm) was carried out using a CEL HXF300 xenon lamp with cutoff filter. UV/vis spectra were recorded on a Shimadzu UV-3600 spectrophotometer equipped with a PTC-348WI temperature controller. The sample for TEM measurements was prepared by dropping the solution onto a copper grid. The grid was then air-dried. The samples were examined by a high-resolution TEM (Tecnai G2 F20 microscope, FEI) equipped with a CCD camera (Orius 832, Gatan) operating at an accelerating voltage with a CCD camera (Orius 832, Gatan) operating at an accelerating voltage of 200Kv. The molecular packing model of supramolecular assemblies voltage of 200 kV. CD spectra were collected on a JASCO J-715 Circular Dichroism spectroimeter.

Scheme S1. Synthetic route of **1** and **2**.



Synthesis of azobenzene-bridged bis(dibenzo-24-crown-8) (1).

4,4'-Dihydroxyazobenzene (60.46 mg, 0.28 mmol) was added to a stirred solution of 4-chloromethylenedibenzo-24-crown-8 ether (350 mg, 0.7 mmol) in acetone (80 ml), to which K_2CO_3 (681.16 mg, 4.94 mmol) was added under argon at room temperature. The mixture was stirred under reflux for 7 days. After cooling to room temperature, the mixture was filtered and the filtrate was evaporated under reduced pressure to remove acetone. The residue was dissolved in chloroform (50 ml) and washed with water (2 × 50 ml), dried with anhydrous $MgSO_4$ and evaporated to a yellow residue which was purified by silica gel column chromatography using chloroform-methanol solution (v/v = 200:1) as elutent to give azobenzene-bridged bis(dibenzo-24-crown-8) (123.8 mg) as a yellow powder (yield 38.97 %). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.7 Hz, 4H), 7.05 (d, *J* = 8.8 Hz, 4H), 6.97 (d, *J* = 5.1 Hz, 4H), 6.88 (s, 10H), 5.03 (s, 4H), 4.16 (s, 16H), 3.92 (s, 16H), 3.83 (s, 16H). ^{13}C NMR (101 MHz, $CDCl_3$): δ159.70, 148.01, 147.86, 147.82, 146.12, 128.44, 123.30, 120.37, 119.79, 114.03, 112.97, 112.70, 112.47, 70.26, 69.17, 68.43, 68.34. MALDI-MS for **1** ($C_{62}H_{74}N_2O_{18}$): calcd. $[M+Na^+]^+$: 1157.4834, found: 1157.4833.

Synthesis of cholesteryl aldehyde benzoate (3).

4-Formylbenzoic acid (555 mg, 3.7 mmol), cholesterol (1.43 g, 3.7 mmol), DMAP (0.23 g, 1.9 mmol) and DCC (0.84 g, 4.07 mmol) were dissolved in chloroform (100 ml). The mixture was stirred 4 h under argon at room temperature. The mixture was evaporated under reduced pressure to remove chloroform. The residue was purified by silica gel column chromatography using petroleum ether-chloroform (v/v = 5:3) as elutent to give product (1.13 g) as a white solid (yield 58.9%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 10.09 (s, 1H), 8.17 (d, *J* = 7.6 Hz, 2H), 7.94 (d, *J* = 8.0 Hz, 2H), 5.42 (s, 1H), 4.89 (s, 1H), 2.46 (d, *J* = 7.6 Hz, 2H), 2.00 (s, 3H), 1.85-1.71 (m, 3H), 1.62-1.44 (m, 7H), 1.38-1.29 (m, 4H), 1.17-1.05 (m, 9H), 0.99 (d, *J* = 7.0 Hz, 3H), 0.91 (d, *J* = 6.2 Hz, 3H), 0.86 (d, *J* = 6.1 Hz, 6H), 0.681 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ190.54, 163.86, 138.38, 138.04, 134.83, 129.11, 128.39, 122.00, 74.35, 55.69, 55.18, 49.06, 38.52, 36.00, 34.79, 30.93, 30.88, 27.22, 27.00, 26.84, 22.85, 21.80, 21.56, 20.06, 18.35, 17.73, 10.86.

Synthesis of methylenebenzylamine benzoic acid cholesterylamine (4).

Cholesteryl aldehyde benzoate (0.518 g, 1 mmol), benzylamine (0.13 g, 1.2 mmol) and triethylamine (0.24 g, 4 mmol) were dissolved in methanol and chloroform. The mixture was stirred under reflux for 1 day under argon. After cooling to room temperature, the sodium borohydride (0.61 g, 16 mmol) was added to the reaction system under ice bath conditions. Then the mixture was stirred 24 h under argon at room temperature. Then water was added to stop the reaction. After the solution was concentrated, the residue was dissolved with CH_2Cl_2 (50 ml) and washed with H_2O (2 × 50 ml). The organic phase was dried by $MgSO_4$ and evaporated off. Then the residue was purified by column chromatography using chloroform as elutent to give product (0.41 g) as a white solid (yield 68.8%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.02 (d, *J* = 8.0 Hz, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 7.34 (d, *J* = 4.2 Hz, 5H), 5.44 (s, 1H), 4.87 (s, 1H), 3.83 (d, *J* = 24.7 Hz, 4H), 2.48 (d, *J* = 7.7 Hz, 2H), 2.10-1.95 (m, 3H), 1.84-1.69 (m, 3H), 1.65-1.44 (m, 7H), 1.43-1.32 (m, 4H), 1.19-1.07 (m, 9H), 1.05-0.99 (m, 3H), 0.95 (d, *J* = 6.3 Hz, 3H), 0.89 (d, *J* = 6.1 Hz, 6H), 0.71 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 165.91, 145.51, 140.08, 139.70, 129.73, 129.58, 128.47, 128.17, 127.92, 127.08, 122.78, 74.52, 56.73, 56.20, 53.17, 52.79, 50.09, 42.37, 39.80, 39.58, 38.29, 37.10, 36.69, 36.25, 35.86, 31.99, 31.93, 28.30, 28.06, 27.96, 24.35, 23.91, 22.90, 22.64, 21.11, 19.44, 18.79, 11.93.

Synthesis of 2.

Methylenebenzylamine benzoic acid cholesterylamine: (154.96 mg, 0.25 mmol), trifluoroacetic acid (144.98 mg, 1.25 mmol) were dissolved in chloroform. The mixture was stirred 2 h at room temperature. Then the solvent was evaporated to obtain a white solid. Then the solid was dissolved in chloroform and methonal. A saturated solution of NH_4PF_6 was added to the solution until no further precipitation was observed. The precipitate was filtered off, washed with water and dried to obtain aim product as a yellow solid (119.1 mg, yield 62%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.01 (d, *J* = 8.2 Hz, 2H), 7.41 (d, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 4.4 Hz,4H) 7.30-7.27(m,1H), 5.42 (d, *J* = 3.9 Hz, 1H), 4.90-4.81 (m, 1H), 3.868 (s, 2H), 3.808 (s, 2H), 2.46 (d, *J* = 7.7 Hz, 2H), 2.07-1.96 (m, 3H), 1.94-1.71 (m, 3H), 1.63-1.42 (m, 7H), 1.40-1.29 (m, 4H), 1.19-1.07 (m, 9H), 1.05-0.98 (m, 3H), 0.93 (d, *J* = 6.5 Hz, 3H),

0.88 (d, J = 1.7 Hz, 3H), 0.87 (d, J = 1.6 Hz, 3H), 0.695 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 164.85, 143.74, 138.65, 138.36, 128.71, 127.48, 127.23, 127.00, 126.20, 121.73, 73.51, 55.68, 55.13, 51.92, 51.52, 49.04, 41.31, 38.73, 38.50, 37.21, 35.64, 35.17, 34.78, 30.92, 30.87, 27.22, 27.00, 26.88, 23.28, 22.82, 21.80, 21.55, 20.04, 18.37, 17.71, 10.85. ESI-MS calcd. $[M–PF_6^-]^-$: 610.4619, found: 610.4620.

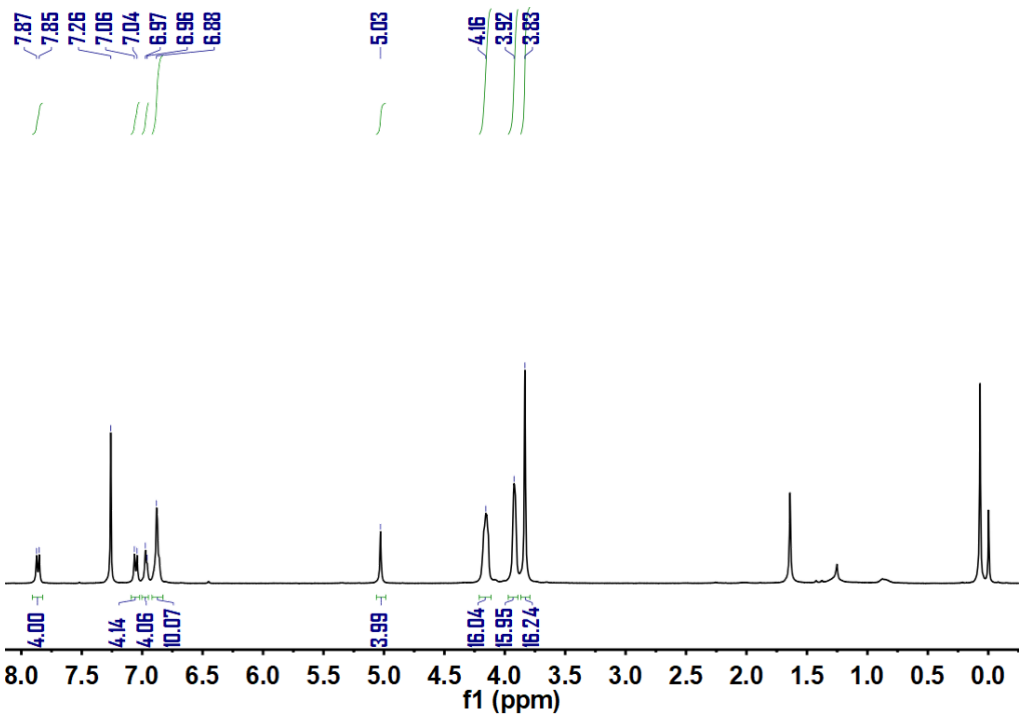


Figure S1. ^{1}H NMR spectrum of **1** in $CDCl_3$, 400 MHz, 298 K.

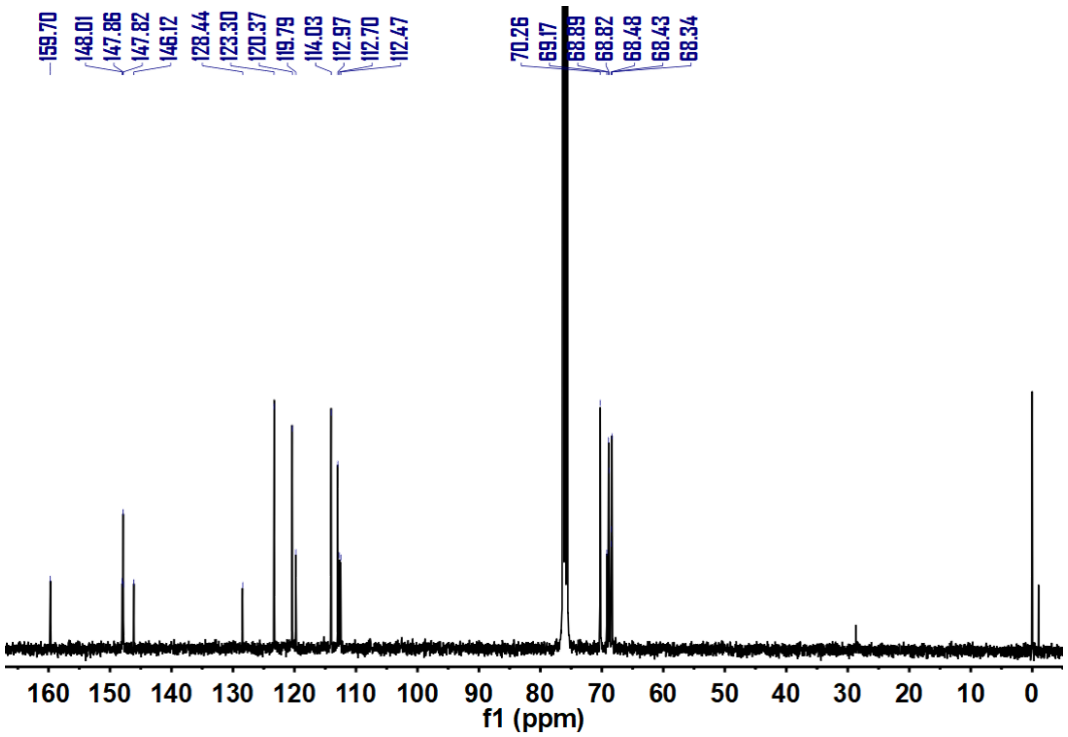


Figure S2. ^{13}C NMR spectrum of **1** in $CDCl_3$, 100 MHz, 298 K.

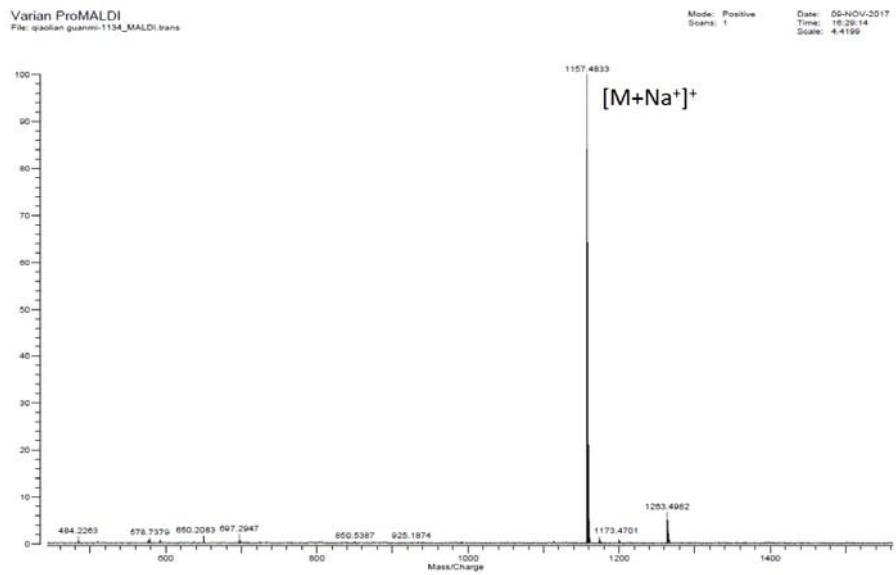


Figure S3. MADILI-TOFMS spectrum of **1** ($C_{62}H_{74}N_2O_{18}$): calcd. $[M+Na^+]^+$: 1157.4834, found: 1157.4833.

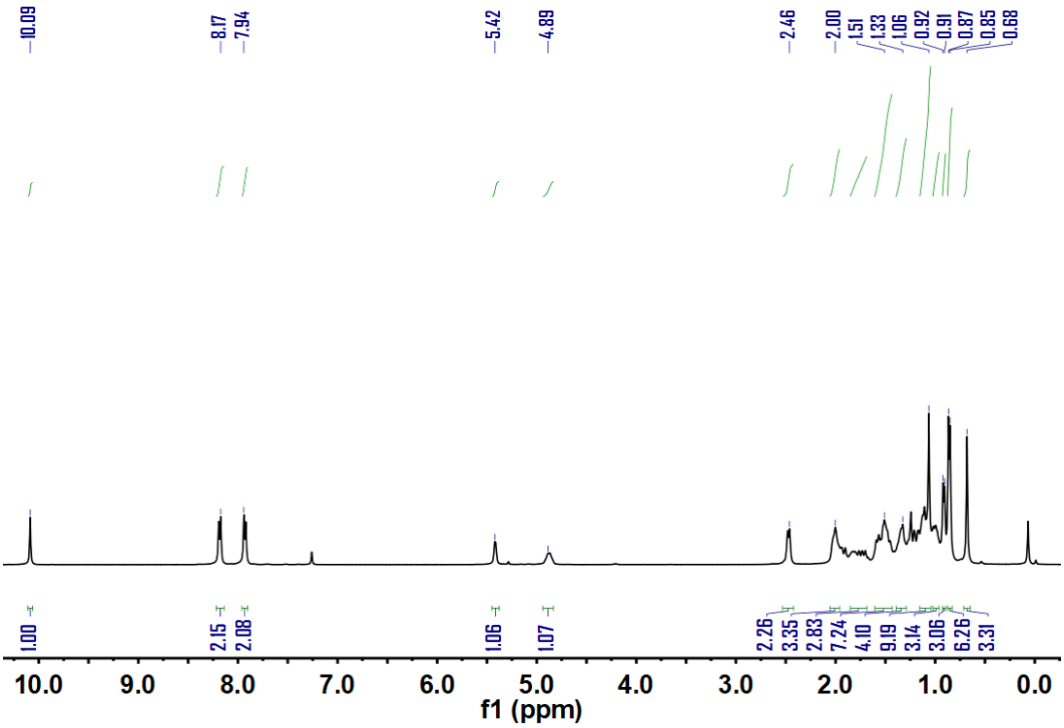


Figure S4. ^{1}H NMR spectrum of **3** in $CDCl_3$, 400 MHz, 298 K.

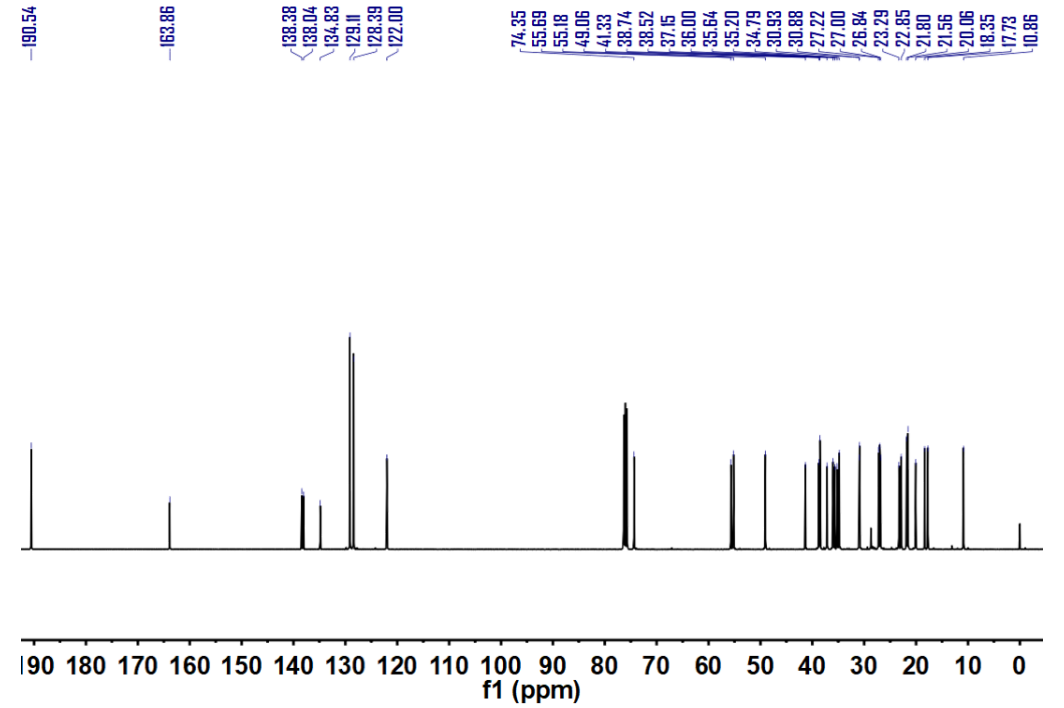


Figure S5. ^{13}C NMR spectrum of **3** in $CDCl_3$, 100 MHz, 298 K.

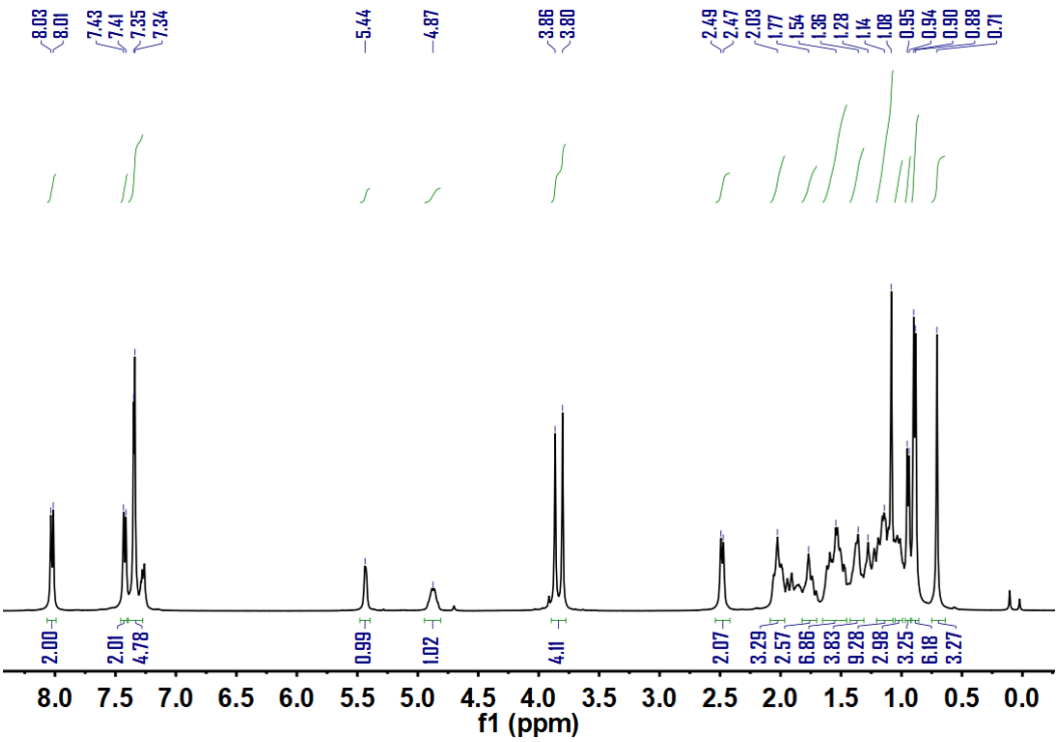


Figure S6. ^{1}H NMR spectrum of **4** in $CDCl_3$, 400 MHz, 298 K.

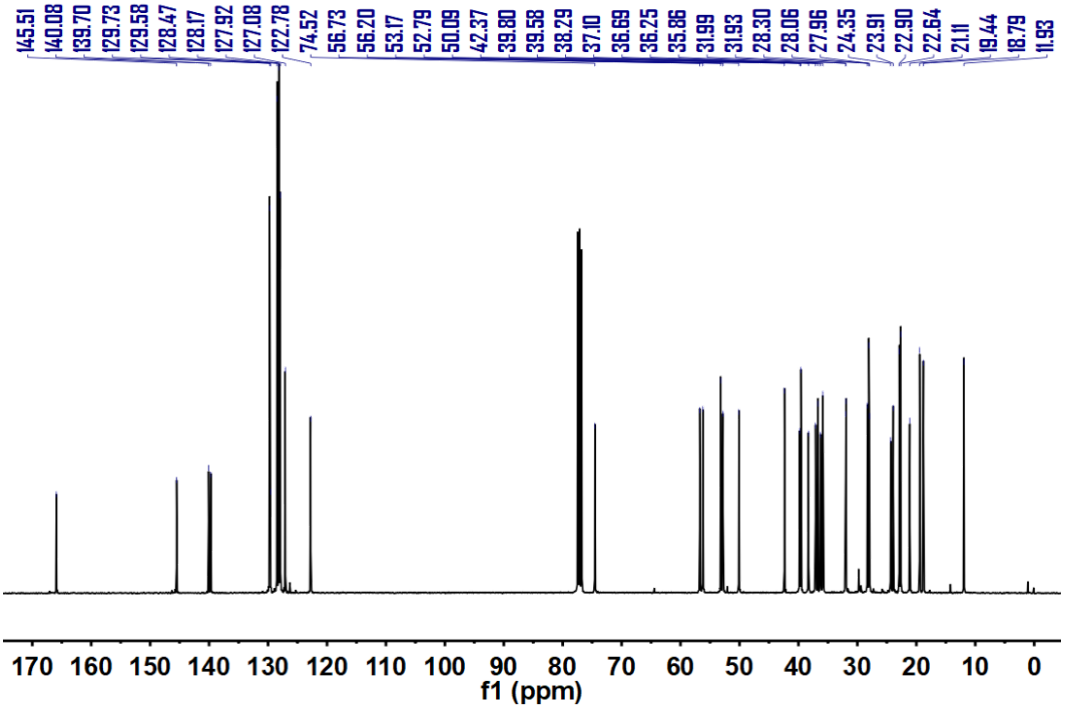


Figure S7. ^{13}C NMR spectrum of **4** in $CDCl_3$, 100 MHz, 298 K.

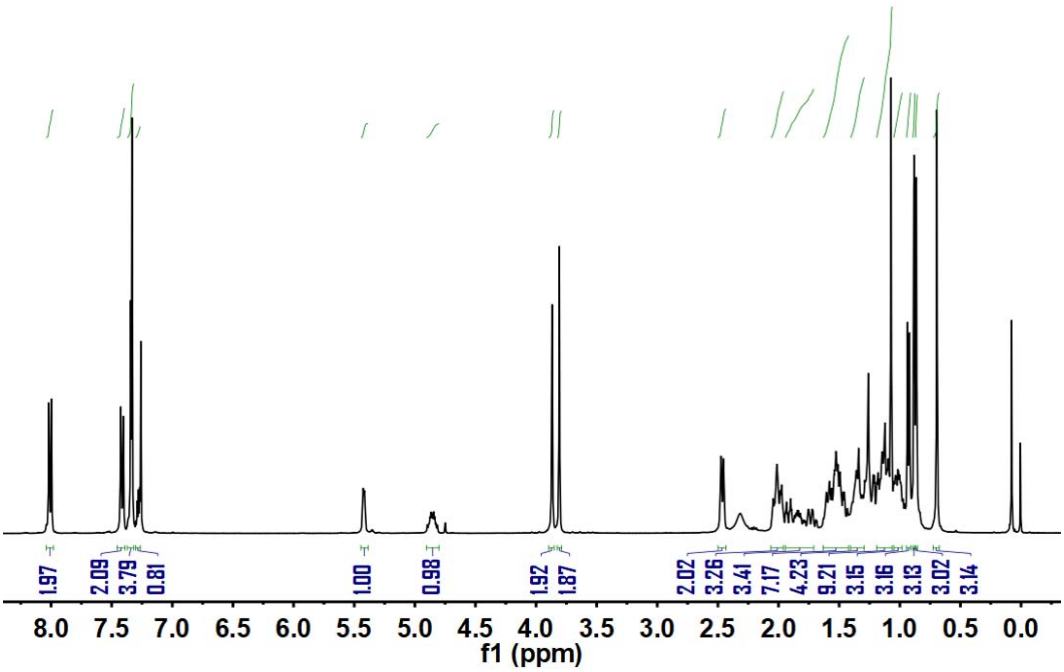


Figure S8. ^{1}H NMR spectrum of **2** in $CDCl_3$, 400 MHz, 298 K.

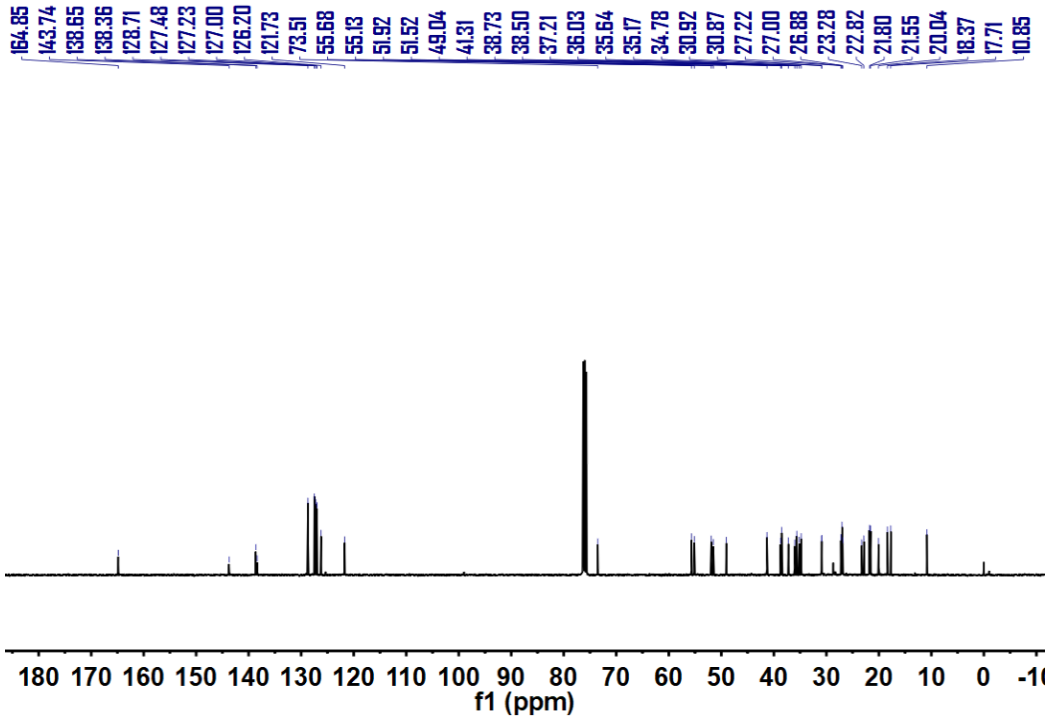


Figure S9. ^{13}C NMR spectrum of **2** in $CDCl_3$, 100 MHz, 298 K.

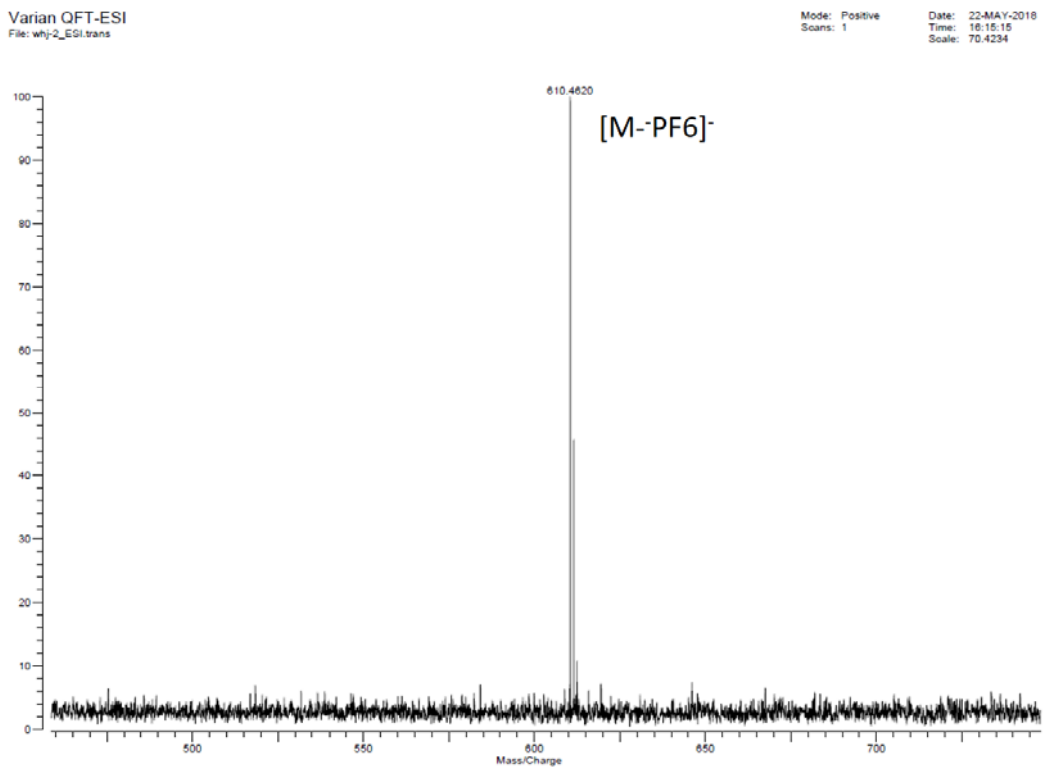


Figure S10. The ESI-MS spectrum of **2** ($C_{42}H_{60}NO_2PF_6$): calcd. [M–PF_6^-]$^-$: 610.4619, found: 610.4620.

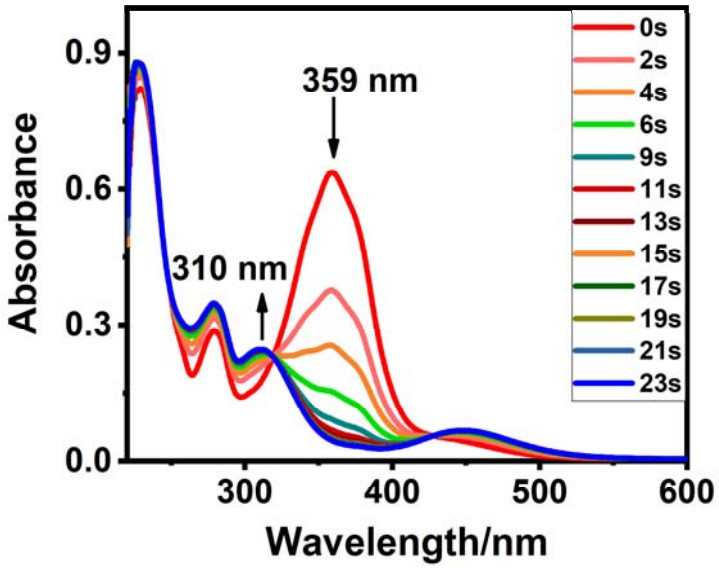


Figure S11. Absorption spectra of **1** upon irradiation at 365 nm for different time in CH_2Cl_2 at 298 K ([**1**] = 3×10^{-5} M).

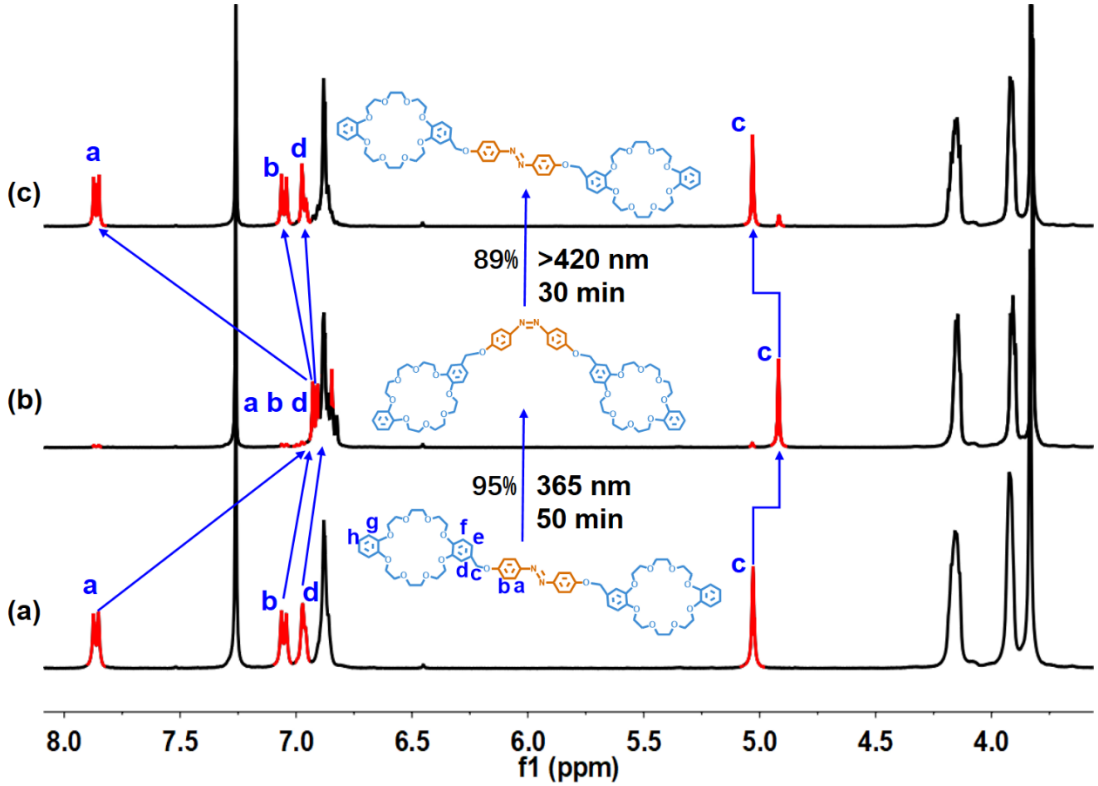


Figure S12. Partial ^{1}H NMR spectra (400 MHz, $CDCl_3$, 298 K) of a) *trans*-**1**, b) sample (a) irradiated with 365 nm light for 50 min, c) sample (b) irradiated with > 420 nm light for 30 min.

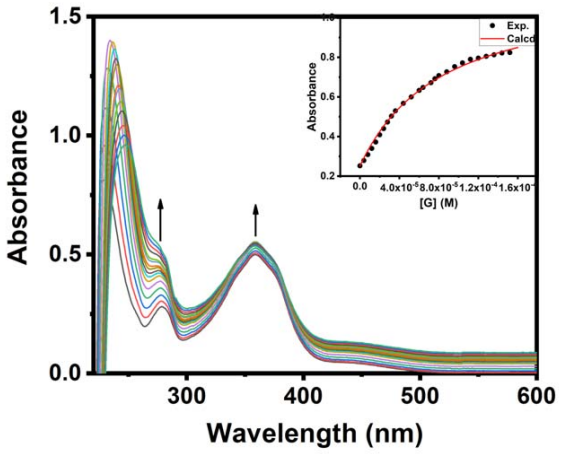


Figure S13. UV-vis titration spectra of *trans*-**1** (2×10^{-5} M) upon addition of **2** ((0-160) $\times 10^{-6}$ M) in CH_2Cl_2 at 298 K, Inset: Nonlinear least sqares fit of the absorption changes at 257 nm to determine the complex stability constant (K_s) as 13400 ± 700 M^{-1}.

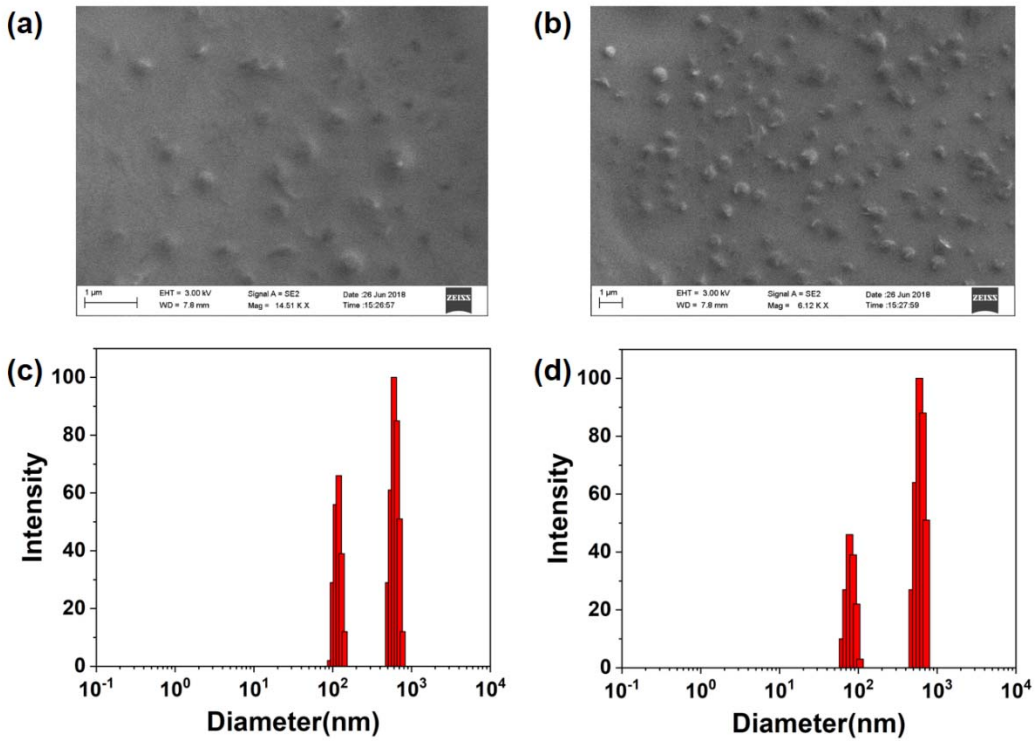
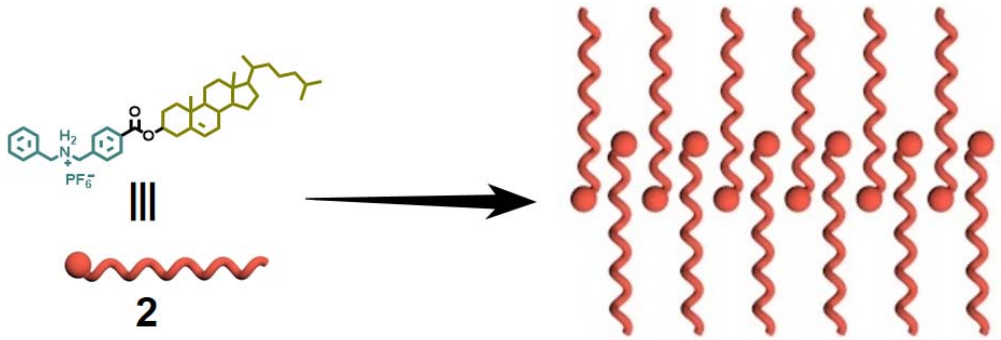


Figure S14. SEM image of a) *trans*-**1**, b) *cis*-**1**, DLS data of c) *trans*-**1**, d) *cis*-**1**. All samples were prepared in CH_2Cl_2 at 298 K. ([*trans*-**1**] = [*cis*-**1**] =3.3 × 10^{-4} M).

Scheme S2. Schematic representations of **2**.



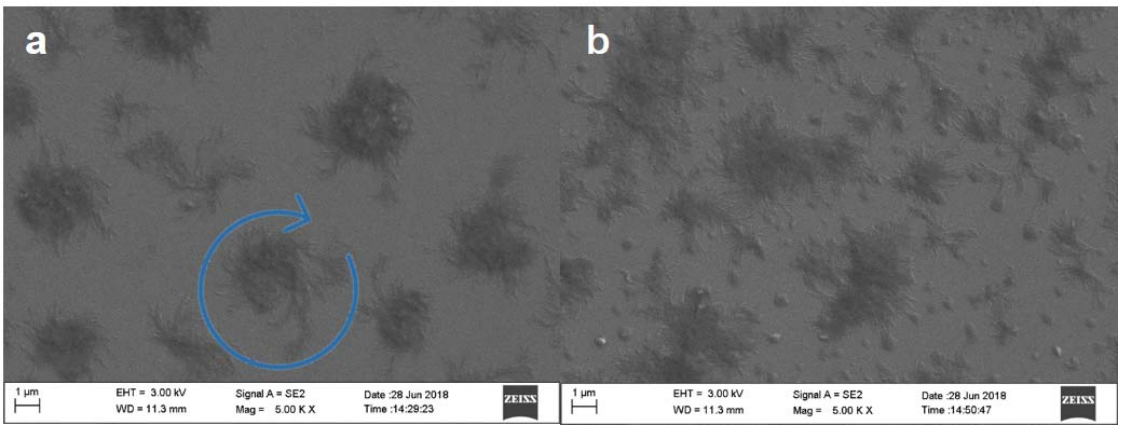


Figure S15. SEM images of **2**⊂*trans*-**1** in CH_2Cl_2 upon the irradiation of 365 nm light for a) 0 min, (**2**⊂*trans*-**1**) b) 50 min (**2**⊂*cis*-**1**) (**1**: **2** = 1:2, [**1**] = 3.3×10^{-4} M).

References

1. M. Han, H.-Y. Zhang, L.-X. Yang, Q. Jiang and Y. Liu, *Org. Lett.* 2008, **10**, 5557-5560.