Supporting Information

Nanofibers from Self-Assembly of an Aromatic Facial Amphiphile with Oligo(ethylene oxide) Dendrons

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Materials

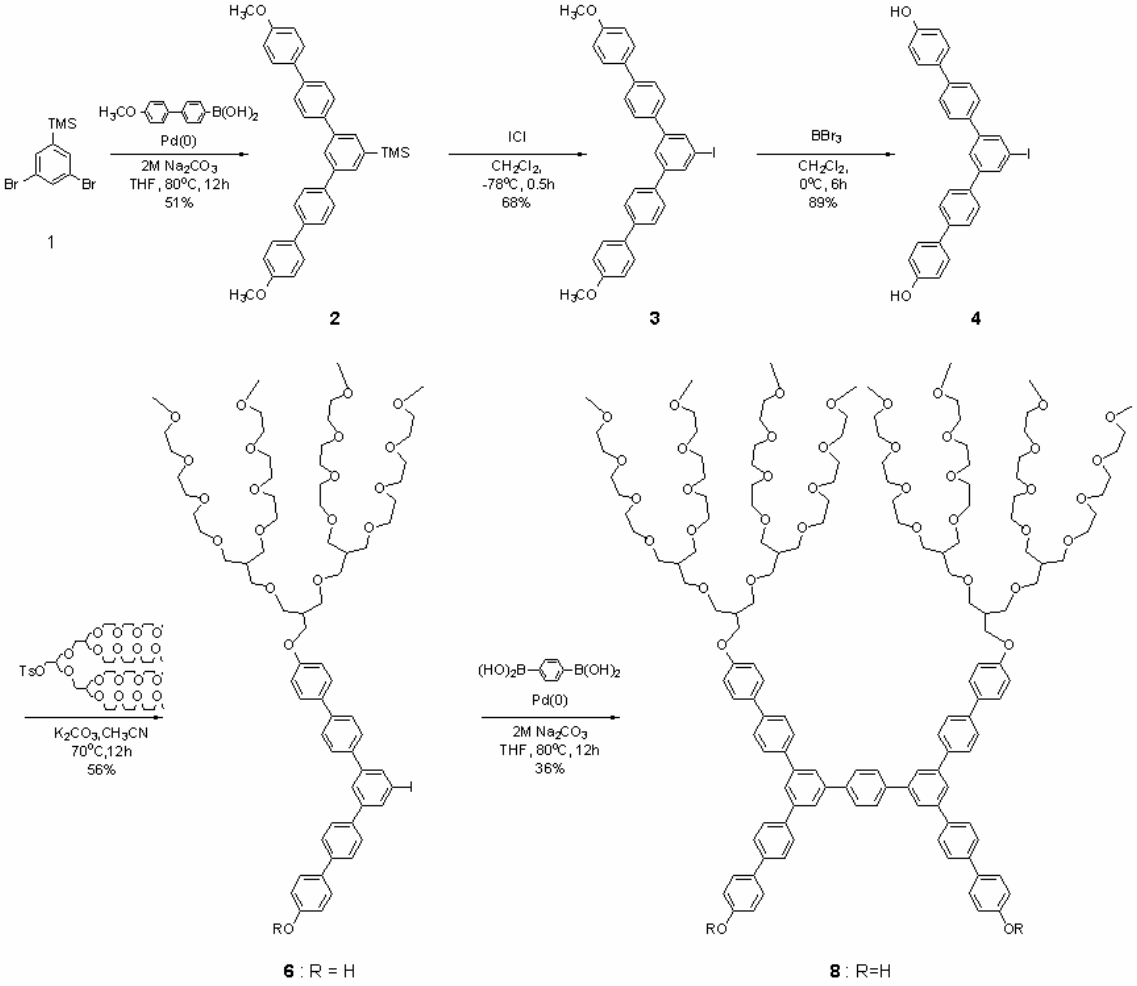
Tetrakis(triphenylphosphine) palladium(0) (99%) from TCI were used as received. Iodine monochloride (1.0 M solution in dichloromethane), benzene 1,4-diboronic acid from Aldrich and the conventional reagents were used as received. 4,4'-Methoxy biphenyl boronic acid, (3,5-dibromophenyl)-trimethylsilane and ROTs were prepared according to the similar procedures described previously. All atmosphere sensitive reactions were done under nitrogen. Visualization was accomplished with UV light and iodine vapor. Flash chromatography was carried out with Silica Gel 60 (230-400 mesh) from EM Science.

Techniques

^{1}H-NMR and ^{13}C-NMR spectra were recorded from $CDCl_3$ solutions on a Bruker AM 250 spectrometer. Microanalysis were performed with a Perkin Elmer 240 elemental analyzer at Organic Chemistry Research Center. The purity of the products was checked by thin layer chromatography (TLC; Merck, silica gel 60). The Microanalysis were performed with a Perkin Elmer 240 elemental analyzer at Organic Chemistry Research Center. MALDI-TOF-MS was performed on a Perseptive Biosystems Voyager-DE STR using a 2, 5-dihydroxy benzoic acid matrix. Preparative

high performance liquid chromatography (HPLC) was performed at room temperature using a 20 mm × 600 mm poly styrene column on a Japan Analytical Industry Model LC-908 recycling preparative HPLC system, equipped with UV detector 310 and RI detector RI-5.

Synthesis



Scheme S1. Synthesis of compound **8**.

Synthesis of compound 2

Compound **1**[1] (4.0 g, 4.08 mmol) and 4,4'-methoxy-biphenyl boronic acid[2] (2.2 g, 9.72 mmol) were dissolved in 70 mL of degassed 2M Na_2CO_3 aqueous solution and

80 mL of THF. Then tetrakis(triphenylphosphine) palladium(0) (22 mg, 0.018 mmol) was added. The mixture was heated at reflux for 48 h with vigorous stirring under nitrogen. Cooled to room temperature, the layers were separated, and the aqueous layer was then washed twice with dichloromethane. The combined organic layer was dried over anhydrous magnesium sulfate and filtered. The solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using dichloromethane / hexane as eluent to yield 0.856 g (51%) of white solid. ^{1}H-NMR (250MHz, $CDCl_3$, δ, ppm) δ = 7.85 (s, 1Ar-H; *p* to Ar-TMS), 7.75-7.58 (m, 14Ar-*H*), 7.03-7.00 (d, 4Ar-*H*; *o* to $ArOCH_3$, *J* = 6.8 Hz), 3.87 (s, 6H; phenylOC*H*$_3$), 0.37 (s, 9H; silane-C*H*$_3$).

Synthesis of compound 3

Compound **2** (0.856 g, 1.67 mmol) in distilled dichloromethane (300 mL) at -78 ^{o}C was dropped 1.0 M solution of ICl in dichloromethane (3.3 mL, 3.3 mmol). The reaction mixture was stirred over 30 min under nitrogen. 1M aqueous $Na_2S_2O_5$ (100 mL) solution was added and stirred over 1 h at room temperature. The layers were separated, and the aqueous layer was then washed twice with dichloromethane. The combined organic layer was dried over anhydrous magnesium sulfate and filtered. The solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using dichloromethane as eluent to yield 0.645 g (68.2%) of a white powder. ^{1}H-NMR (250MHz, $CDCl_3$, δ, ppm) δ = 7.95 (s, 2Ar-*H*; *o* to Ar-I), 7.82 (s, Ar-*H*; *p* to Ar-I), 7.70-7.61 (m, 8Ar-*H*), 7.60-7.58 (d, 4Ar-*H*; *p* to ArO, *J* = 6.7 Hz), 7.02-6.99 (d, 4Ar-*H*; *o* to ArO, *J* = 6.8 Hz), 3.87 (s, 6H; phenylOC*H*$_3$).

Synthesis of compound 4

Compound **3** (0.645 g, 1.13 mmol) was dissolved in 100 mL of distilled dichloromethane then dropping BBr_3 (5.6 mL, 5.6 mmol) slowly at 0 ^{o}C. The reaction mixture was stirred at room temperature under nitrogen for 6 h. The solution was quenched with MeOH at 0 ^{o}C for 30 min. Then 1M aqueous $Na_2S_2O_5$ (50 mL) solution was added and stirred over 1 h at room temperature and the resulting solution was evaporated. The mixture was washed with water and ethyl acetate. The combined organic solution was dried over anhydrous magnesium sulfate and filtered. The solvent was removed in a rotatory evaporator, and the crude product was purified by column

chromatography (silica gel, ethyl acetate) to yield 0.550 g (89.7%) of a white solid. ^{1}H-NMR (250MHz, $CDCl_3$, δ, ppm) δ = 7.94 (s, 2Ar-*H*; *o* to Ar-I), 7.81 (s, Ar-*H*; *p* to Ar-I), 7.65-7.62 (m, 8Ar-*H*), 7.56-7.53 (d, 4Ar-*H*; *p* to ArOH, *J* = 6.7 Hz), 6.93-6.92 (d, 4Ar-*H*; *o* to ArO, *J* = 8.65 Hz).

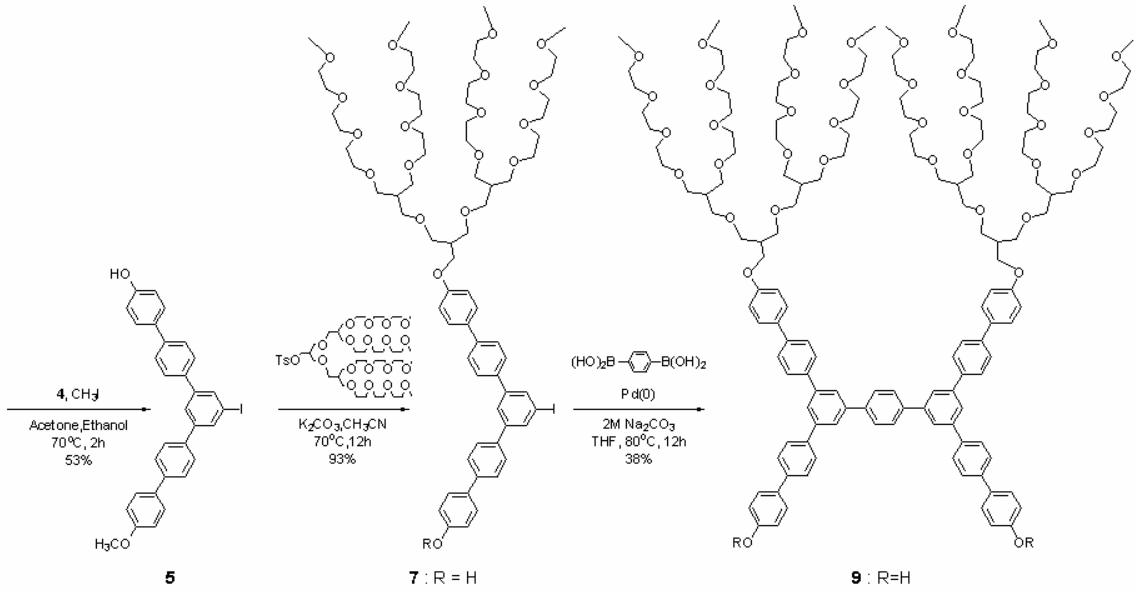
Synthesis of compound 6

Compound **4** (0.55 g, 1.02 mmol) and tosylated 2nd generation of triethyleneoxide[2] (R_1OTs) (1.0 g, 1.0 mmol) and excess K_2CO_3 were dissolved in 100 mL of anhydrous acetonitrile. The mixture was heated at reflux for 12 h. After evaporated solvent, the resulting solution was poured into water and extracted with dichloromethane. The methylene chloride solution was washed with water, dried over anhydrous magnesium sulfate, and filtered, solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using ethyl acetate : methanol (10:1 v/v) as eluent to yield 0.79 g (56%) of a colorless liquid. ^{1}H-NMR (250 MHz, $CDCl_3$, ppm) δ = 7.89 (s, 2Ar-*H*; *o* to Ar-I), 7.76 (s, Ar-*H*; *p* to Ar-I), 7.60-7.45 (m, 12Ar-*H*), 6.96-6.89 (t, 4Ar-*H*; *o* to ArO, *J* = 9.0 Hz), 4.11-4.08 (d, 4H; ArOC*H*$_2$CH(CH$_2$)$_2$, *J*=7.1 Hz), 3.63-3.34 (m, 66H;OC*H*$_2$, 12H; OC*H*$_3$) 2.41-2.14 (m, 3H; C*H*(OCH$_2$)$_2$).

Synthesis of compound 8

Compound **6** (0.79 g, 5.70 mmol) and benzene 1,4-diboronic acid (0.037 g, 0.22 mmol) were dissolved in 70 ml of degassed 2M Na_2CO_3 aqueous solution and 80 mL of THF. Then tetrakis(triphenylphosphine) palladium(0) (22 mg, 0.018 mmol) was added. The mixture was heated at reflux for 48 h with vigorous stirring under nitrogen. Cooled to room temperature, the layers were separated, and the aqueous layer was then washed twice with methylene chloride. The combined organic layer was dried over anhydrous magnesium sulfate and filtered. The solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using ethyl acetate : methanol (10:1 v/v) as eluent to yield 0.21 g (36%) of waxy solid. ^{1}H-NMR (250 MHz, $CDCl_3$, ppm) δ = 7.78-7.37 (m, 34Ar-*H*), 6.93-6.90 (d, 4Ar-*H*; *o* to Ar-OH, *J*=8.45 Hz), 6.85-6.82 (d, 4Ar-*H*; *o* to Ar-OCH$_2$, *J*=8.90 Hz), 3.97-3.95 (d, 4H; ArOC*H*$_2$CH(CH$_2$)$_2$, *J*=5.10 Hz), 3.65-3.49 (m, 132H;OC*H*$_2$), 3.36 (s, 24H; OC*H*$_3$), 2.37-2.04 (m, 6H; C*H*(OCH$_2$)$_2$); ^{13}C-NMR (400 MHz, $CDCl_3$, ppm) δ = 159.2, 158.7,

142.4, 140.4, 128.4, 128.0, 127.8, 127.4, 115.2, 77.6, 77.4, 72.3, 70.9, 70.0 69.6, 66.5, 59.4, 40.5, 40.4; Anal. Calcd for: $C_{146}H_{206}O_{40}$: C, 67.41; H, 7.98 Found C, 67.51; H, 8.23; MALDI-TOF-MS m/z 2623.1 ($[M+Na]^+$), Calcd 2601.17.



Scheme S2. Synthesis of compound **9**.

Synthesis of compound 5

Compound **4** (0.5 g, 0.93 mmol) and iodomethane (0.13 g, 0.93 mmol) and excess K_2CO_3 were dissolved in 100 mL of acetone/ethanol (1:1 v/v). The mixture was heated at reflux for 2h. After evaporated solvent, the resulting solution was poured into water and extracted with ethyl acetate. The ethyl acetate solution was washed with water, dried over anhydrous magnesium sulfate, and filtered, solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using methylene chloride : hexane (1:1 v/v) as eluent to yield 0.27 g (53%) of a white solid. ^{1}H-NMR (250 MHz, $CDCl_3$, ppm) δ = 7.95 (s, 2Ar-*H*; *o* to Ar-I), 7.81 (s, Ar-*H*; *p* to Ar-I), 7.66-7.52 (m, 12Ar-*H*), 7.02-6.99 (d, 2Ar-*H*; *o* to ArO, *J* = 8.7 Hz), 6.95-6.92 (d, 2Ar-*H*; *o* to $ArOCH_3$, *J* = 8.6 Hz), 3.87 (s, 3H; phenylOCH_3).

Synthesis of compound 7

Compound **5** (0.27 g, 0.49 mmol) and tosylated 2nd generation of triethyleneoxide[2] (R_1OTs) (0.50 g, 0.49 mmol) and excess K_2CO_3 were dissolved in 100 mL of anhydrous acetonitrile. The mixture was heated at reflux for 12 h. After evaporated solvent, the resulting solution was poured into water and extracted with dichloromethane. The dichloromethane solution was washed with water, dried over anhydrous magnesium sulfate, and filtered, solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using ethyl acetate : methanol (10:1 v/v) as eluent to yield 0.49 g (73%) of a colorless liquid. ^{1}H-NMR (250 MHz, $CDCl_3$, ppm) δ = 7.9 (s, 2Ar-*H*; *o* to Ar-I), 7.80 (s, Ar-*H*; *p* to Ar-I), 7.69-7.54 (m, 12Ar-*H*), 7.01-6.97 (d, 4Ar-*H*; *o* to ArO, *J* = 8.8 Hz), 4.06 (d, 2H; ArOCH_2CH$(CH_2)_2$, *J*=7.1 Hz), 3.85 (s, 3H; phenylOCH_3), 3.64-3.36 (m, 66H;OCH_2, 12H; OCH_3) 2.44-2.15 (m, 3H; C*H*$(OCH_2)_2$).

Synthesis of compound 9

Compound **7** (0.49 g, 0.35 mmol) and benzene 1,4-diboronic acid (0.058 g, 0.35 mmol) were dissolved in 70 ml of degassed 2M Na_2CO_3 aqueous solution and 80 mL of THF. Then tetrakis(triphenylphosphine) palladium(0) (22 mg, 0.018 mmol) was added. The mixture was heated at reflux for 48 h with vigorous stirring under nitrogen. Cooled to room temperature, the layers were separated, and the aqueous layer was then washed twice with methylene chloride. The combined organic layer was dried over anhydrous magnesium sulfate and filtered. The solvent was removed in a rotary evaporator, and the crude product was purified by column chromatography (silica gel) using ethyl acetate : methanol (10:1 v/v) as eluent to yield 0.35 g (38%) of waxy solid. ^{1}H-NMR (250 MHz, $CDCl_3$, ppm) δ = 7.94-7.50 (m, 34Ar-*H*), 7.03-7.02 (d, 4Ar-*H*; *o* to Ar-OH, *J*=2.60 Hz), 7.00-6.99 (d, 4Ar-*H*; *o* to Ar-OCH_2, *J*=2.55 Hz), 4.07-4.05 (d, 4H; ArOCH_2CH$(CH_2)_2$, *J*=5.10 Hz), 3.87 (s, 6H; phenylOCH_3), 3.64-3.46 (m, 132H;OCH_2), 3.36 (s, 24H; OCH_3), 2.40-2.21 (m, 6H; C*H*$(OCH_2)_2$); ^{13}C-NMR (400 MHz, $CDCl_3$, ppm) δ = 159.2, 158.8, 142.0, 140.1, 139.3, 133.1, 132.9, 128.1, 127.8, 127.7, 124.9, 114.8, 114.2, 76.5, 71.9, 70.6, 70.5, 70.4 69.6, 69.4, 69.2, 66.1, 59.0, 55.3, 40.1, 39.9; Anal. Calcd for: $C_{148}H_{210}O_{40}$: C, 67.61; H, 8.05 Found C, 67.58; H, 8.09; MALDI-TOF-MS m/z 2650.3 ($[M+Na]^+$), Calcd 2627.44.

Dynamic Laser Light Scattering Experiments

Dynamic light scattering measurements were performed using the maximum operating power of the laser was 30mW. The detector optics employed optical fibers coupled to an ALV/SO-SIPD/DUAL detection unit, which employed an EMI PM-28B power supply and ALV/PM-PD preamplifier/discriminator. The signal analyzer was an ALV-5000/E/WIN multiple tau digital correlator with 288 exponentially spaced channels. The dynamic light scattering (DLS) were performed with the aqueous solution of molecule 9 (0.01 wt%) over scattering angle range of 30° to 150° at 25℃, using UNIPHASE He-Ne laser operating at 632.8 nm. The CONTIN analysis of the autocorrelation function at a scattering angle of 90° showed a broad peak corresponding to an average hydrodynamic radius (R_h) of approximately 125 nm (Figure S1a). The angular dependence of the apparent diffusion coefficient (D_{app}) was measured because the slope is related to the shape of the diffusing species. As shown in Figure S1d, the slope is 0.02, consistent with the value predicted for elongated non-spherical micelles (0.03).

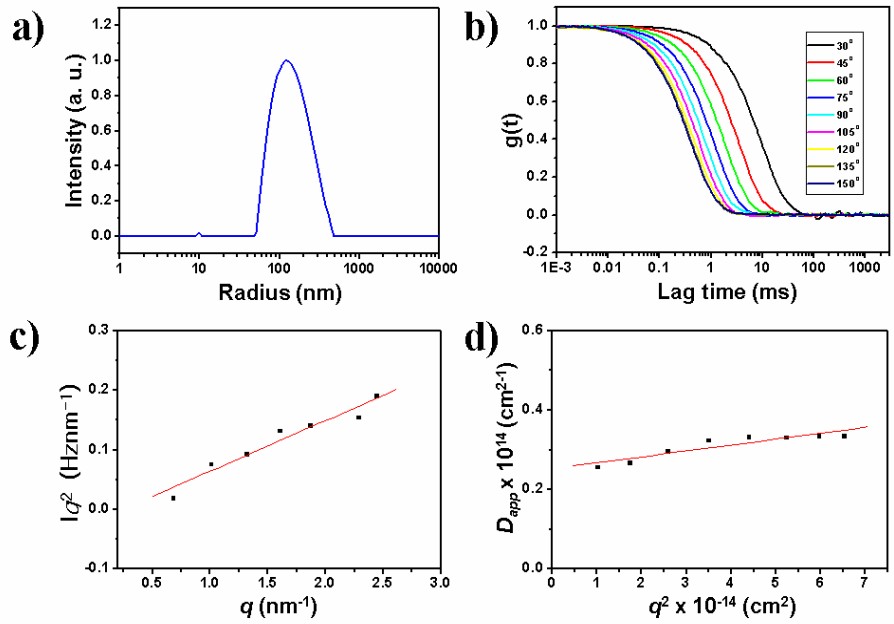


Figure S1. (a) Size distribution of compound **9** at scattering angle of 90° (from CONTIN analysis). (b) Autocorrelation functions of compound **9** in aqueous solution. (c) Kratky plot of compound **9**. (d) Angular dependence of diffusion coefficient for compound **9**.

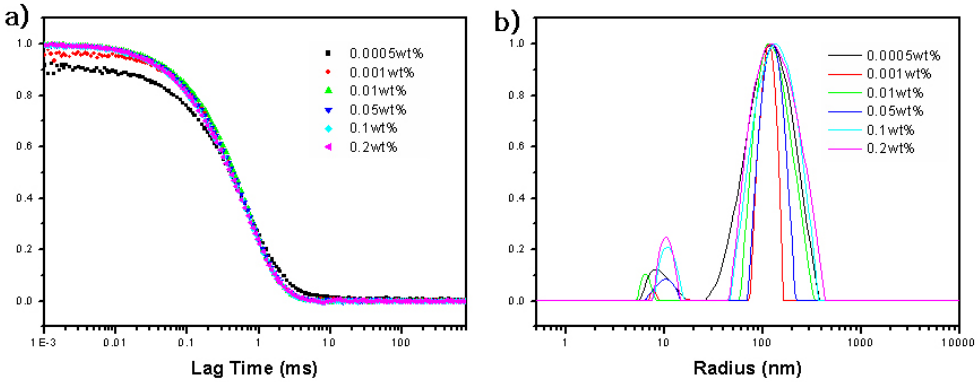


Figure S2. (a) Autocorrelation functions and (b) size distribution (at scattering angle of 90 ^{o} from CONTIN analysis) of compound **8** in aqueous solution with concentration variation.

Dye Encapsulation Experiment

Dye encapsulation experiment was performed to confirm hydrophobic core structure of facial amphiphiles in aqueous solution. To 2ml of aqueous solution (0.0025 wt%), approximately 1.2 mg of hydrophobic dye, Nile Red, was added and was sonicated for 3 h at room temperature. Then the solution was filtered to obtain clear solution.

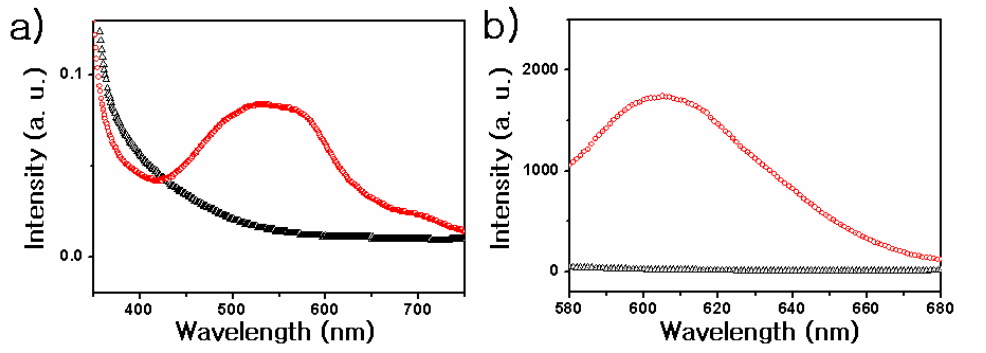


Figure S3. (a) Absorption spectra of Nile Red solubilized with **9** in water (red line). (b) Emission spectra of Nile Red solubilized with **9** in water (red line)..

TEM Experiments

The transmission electron microscope (TEM) was performed at 120 kV using JEOL 2010. For TEM image of compound **8** and **9** in aqueous solution, one drop of aqueous solution of compound **8** and **9** (0.01 wt %) was placed on a carbon-coated copper grid, respectively, and dried at room temperature. The formation of non-spherical aggregates in aqueous solution was also provided by transmission electron microscopy (TEM) experiments. The negatively stained sample with uranyl acetate clearly shows 1-dimensional nanofibers with a uniform diameter of 7 nm. Considering that the fully extended molecular length of the amphiphilic molecule is estimated to be ~4 nm from the molecular modeling, the 7 nm width is consistent with a bilayer packing of aromatic segments.

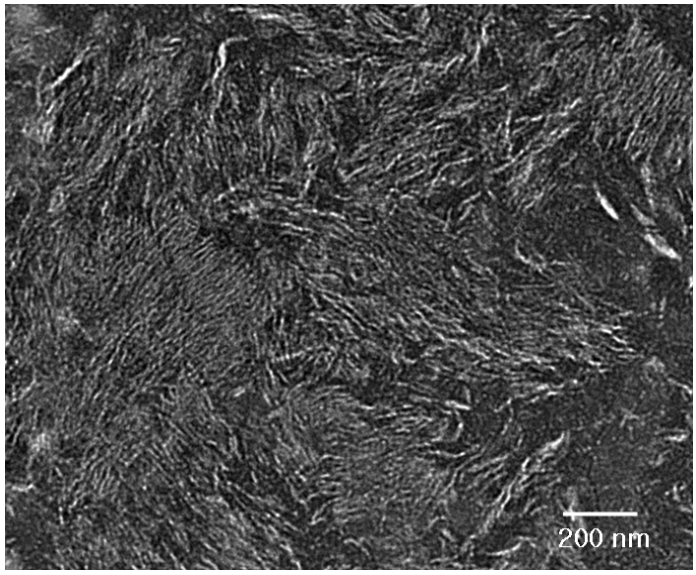


Figure S4. TEM image of compound **9** in aqueous with magnification.

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Reference

(S1) Y.-S. Yoo and M. Lee, *J. Mater. Chem.* 2005, **15**, 419-423

(S2) C. -J. Jang, J.-H. Ryu, J. -D. Lee, D. Sohn and M. Lee, *Chem. Mater.* 2004, **16**, 4226-4231.