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Electronic Supplementary Information

Supramolecular Behavior of Fluorous Polyglycerol Dendrons and Polyglycerol Dendrimers with Perfluorinated Shells in Water

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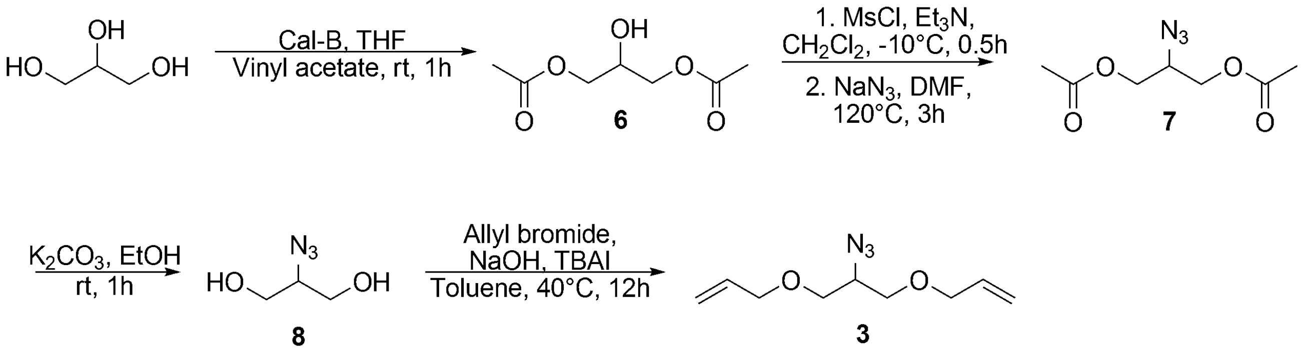
General. ^{1}H NMR and ^{13}C NMR spectra were recorded on ECX 400 (400 and 100 MHz for ^{1}H and ^{13}C, respectively) as well as Delta JEOL Eclipse 500 (500 for ^{1}H, 125 MHz for ^{13}C, and 470 MHz for ^{19}F) spectrometers at 25 °C. AMX 500 and ECX 400 were used to record high resolution 13C NMR. The spectra were calibrated using the solvent peak ($CDCl_3$, 7.26 ppm for ^{1}H and 77.0 ppm for ^{13}C; CD_3OD, 4.84 ppm for ^{1}H and 49.05 ppm for ^{13}C). Flash chromatography was performed on silica gel 60 (230-400 mesh) using head pressure by means of compressed air. For ESI-TOF measurements an Agilent 6210 ESI-TOF, Agilent Technologies, Santa Clara, U.S.A., and for ESI-FTICR MS (electrospray ionization-Fourier transform ion cyclotron resonance mass spectrometry) measurements, an Ionspec QFT-7, Varian Inc., Lake Forest, U.S.A., were used. HPLC was carried out on a Knauer HPLC (pump K-1800) using a Knauer RI-detector K-2401 and a Nucleosil 50-5 (32 × 240) column.

Reagents. All reagents were purchased from Acros or Aldrich and used as received, unless stated otherwise. Reactions requiring dry conditions were carried out in dried Schlenk glassware under argon. Dry and analytical grade solvents were purchased from Acros or Aldrich and used as received.

1. Synthesis of diallyl azide compound (3).



SI-Scheme 1. Synthesis of diallyl azide compound **3**.

Synthesis of 2-hydroxypropane-1,3-diyl diacetate (6)

Glycerol (5 g, 1.0 equiv., 54.28 mmol), 1.5 g of Novozyme 435 and vinyl acetate (12.15 g, 141.17 mmol, 2.6 equiv.) were dissolved in 200 mL THF and stirred for 1h at room temperature. After the completion of the reaction Novozyme 435 was filtered off and washed three times with MeOH. Solvents were removed in vacuo, the residue was purified via flash chromatography using AcOEt:MeOH (1:4.5 → 3:2, v/v) as an eluent giving **6** (9.54 g, 99.8 %) as colorless liquid.

^{1}H NMR (400 MHz, $CDCl_3$, 25°C): δ = 4.13-4.00 (m, 5 H, C*H*(OH)C*H*$_2$), 3.01 (br s, 1 H, -O*H*), 2.03 (s, 6 H, OCOC*H*$_3$) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, 25°C): δ = 171.02, 67.72, 65.03, 20.63 ppm. ESI-TOF MS: cal. $C_7H_{12}O_5$ (176.0685); found 199.0528 $[M + Na]^+$.

Synthesis of 2-azidopropane-1,3-diyl diacetate (7)

Methanesulfonyl chloride (5.06 mL, 65.55 mmol, 1.1 equiv.) was added to a solution of **6** (10.0 g, 62.43 mmol, 1.0 equiv.) and triethylamine (9.21 mL, 65.55 mmol, 1.1 equiv.) in DCM (160 mL), cooled to –10 °C in an ice bath. Progress of the reaction was monitored by TLC. After completion, the precipitate was filtered and the mixture concentrated in vacuo to give oil as a final product. The crude product was used for the next reaction step.

^{1}H NMR (250 MHz, $CDCl_3$, 25°C): δ = 4.99 (tt, 1 H, *J* = 3.8, 6.5 Hz, C*H*-CH_2) 4.26 (ddd, 4 H, *J* = 5.2, 12.3, 18.9 Hz, CH-CH_2), 3.06 (s, 3 H, -OSO_2CH_3), 2.08 (s, 6 H, OCOCH_3) ppm. ^{13}C NMR (100MHz, $CDCl_3$, 25°C): δ = 170.08, 76.37, 62.19, 38.39, 20.45 ppm.

Sodium azide (0.436 mol, 28.4 g, 5.0 equiv.) was added to a solution of **[G0]-OMs-Acet** (0.087 mol, 22.2 g, 1.0 equiv.) in dry DMF (150 mL). After the mixture had been stirred at 120 °C under argon for 3 h, the excess of NaN_3 was filtered off, and DMF was removed under high vacuum by cryodistillation. The crude product was purified by filtration through a thin layer of silica gel with AcOEt/*n*-hexane (3:2, v/v) as an eluent. **7** was obtained as a light yellow oil in 95% yield over two steps.

^{1}H NMR (250 MHz, $CDCl_3$, 25 °C): δ = 4.10 (dq, 4 H, *J* = 5.7, 11.6 Hz, CH-CH_2), 3.83 (m, 1 H, C*H*-CH_2), 2.04 (s, 6 H, OCOCH_3) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, 25°C): δ = 170.08, 62.88, 58.25, 20.35 ppm. ESI-TOF MS: cal. $C_7H_{11}N_3O_4$ (201.0750); found 224.0648 $[M + Na]^+$.

Synthesis of 2-azidopropane-1,3-diol (8)

To compound **7** (9.57 g, 47.57 mmol, 1.0 equiv.) dissolved in ethanol (100 mL) 2.5 equiv. of K_2CO_3 (16.44 g, 199 mmol) were added and stirred for 30 min at room temperature. After completion of the reaction, white solid was filtered off and washed twice with ethanol. The combined filtrates were removed under vacuum and the residue without any purification give desired azido glycerol (**8**) as pale yellow liquid (5.57 g, 47.57 mmol, 99 %).

^{1}H NMR (250 MHz, CD_3OD, 25 °C): δ = 3.64-3.48 (m, 5 H) ppm. ^{13}C NMR (62.9 MHz, CD_3OD, 25°C): δ = 68.92, 65.12 ppm. ES-MS: cal. $C_3H_7N_3O_3$ (117.0538); found: 117.0 $[M]^{+\cdot}$ (0.25), 99.0 $[M - H_2O]^{+\cdot}$(5.03).

Synthesis of 3-(3-(allyloxy)-2-azidopropoxy)prop-1-ene (3)

Allyl bromide (18.4 g, 152.1 mmol, 2.5 equiv. per OH group) was added to a solution of the alcohol **8** (3.56 g, 30.42 mmol, 1.0 equiv.) and TBAI (10 mol-%, 1.12 g) as phase-transfer catalyst in aqueous NaOH (50% w/v) (212.17 g, 0.152 mmol., 5.0 equiv. per OH group). The reaction mixture was then stirred over night at 40 °C. After addition of *n*-hexane and sat. NH_4Cl, the organic phase was separated, washed with water, dried with Na_2SO_4 and concentrated under vacuum. The crude product was further purified by column chromatography on silica gel to give the product **3** (5.0 g, 90 %) as colorless oil.

^{1}H NMR (400 MHz, $CDCl_3$, 25°C): δ = 5.87 (tdd, 2 H, *J* = 5.6, 10.6, 17.2 Hz, $OCH_2CH{=}CH_2$), 5.26 (qd, 2 H, *J* = 1.6, 17.2 Hz, $OCH_2CH{=}CH_2$), 5.17 (ddd, 2 H, *J* = 1.3, 2.9, 10.4 Hz, $OCH_2CH{=}CH_2$), 3.99 (td, 4 H, *J* = 1.4, 5.6 Hz, $OCH_2CH{=}CH_2$), 3.70 (tt, 1 H, *J* =4.6, 6.5 Hz, $CH(N_3)CH_2O$), 3.53 (ddd, 4 H, *J* = 5.6, 10, 16.6 Hz, $CH(N_3)CH_2O$) ppm. ^{13}C NMR (100 MHz, $CDCl_3$, 25°C): δ = 134.31, 117.37, 72.38, 69.80, 60.80 ppm. ESI-TOF MS: cal. for $C_9H_{15}N_3O_2$ (197.1164); found 198.1253 $[M + H]^+$, 220.1077 $[M + Na]^+$, 236.0822 $[M + K]^+$.

2. Experimental Procedures

CMC Determination. The critical micelle concentration (CMC) of the [G3] bi-perfluoro-tagged glycerol dendron was determined by measuring the surface tension of the amphiphiles in deionized water (Milipore system Milli-Q plus) by the pendant drop method. The contact angle tensiometer OCA20 (DataPhysics Instruments GmbH, Filderstadt, Germany) was used for these measurements and the temperature was set at 25±0.5 °C. Calculation of the surface tension was done by using the Young–Laplace-Equation. The accuracy of measurements, checked by one replicate experiment and by control of the surface tension for pure water, was ±0.4 mN/m. The behaviour of the amphiphiles in water was studied over the concentration range of 4×10^{-7} to 1×10^{-3} M. Aqueous solutions were prepared 24 h before measurement. The surface tension was determined twice per minute and the measurement was stopped when the value did not change by more than 0.1mN/m over three minutes. Equilibration time was generally between 50–80 min below the CMC and 25–50 min at higher concentrations.

Optical Microscopy. The images of the micron-sized bubbles formed in water were recorded on a Zeiss Axioskop 40 Pol. The images were recorded at r.t. and were evaluated with AxioVision® 3.1. Objectives used were LD EC-Epiplan-NEOFLUAR 20x/0.22DIC and EC-Epiplan-NEOFLUAR 50x/0.55DIC. Samples of the various dendron-dendrimer ratios were prepared by dissolving a certain amount of polyglycerol dendrimer with perfluorinated shell ($1.06*10^{-3}$ M) in a solution of the [G3] bi-perfluoro-tagged glycerol dendron in water. To ensure proper mixing and dissolution of the compounds all solutions were homogenized by ultrasonication for half an hour. As solvents, distilled water was used. 20 µL of the samples were placed on a microscope slide (76 x 26 mm) and covered with an additional thinner slide for visualization.

Dynamic Light Scattering (DLS). Dynamic Light Scattering measurements were conducted in Millipore filtered water using a Zetasizer Nano (Malvern Instruments Ltd.). Aqueous solutions were prepared 24 h before measurement. Samples of dendron-dendrimer ratios were prepared by dissolving a certain amount of polyglycerol dendrimer with perfluorinated shell ($1.06*10^{-3}$M) in a solution of the [G3] bi-perfluoro-tagged glycerol dendron in water.

Transmission Electron Microscopy (TEM). Transmission Electron Microscopy samples were prepared on copper grids (400 mesh) coated with 0.1 % collodion/C-film. Samples were blotted (drop of 5 µL) after 60 s and stained with 4.5 % aqueous phosphotungstic acid/0.1 % trehalose after 30 or 60 s and visualized using a FEI CM12 Electron Microscope at 100 kV high tension.

1. Supporting Figures

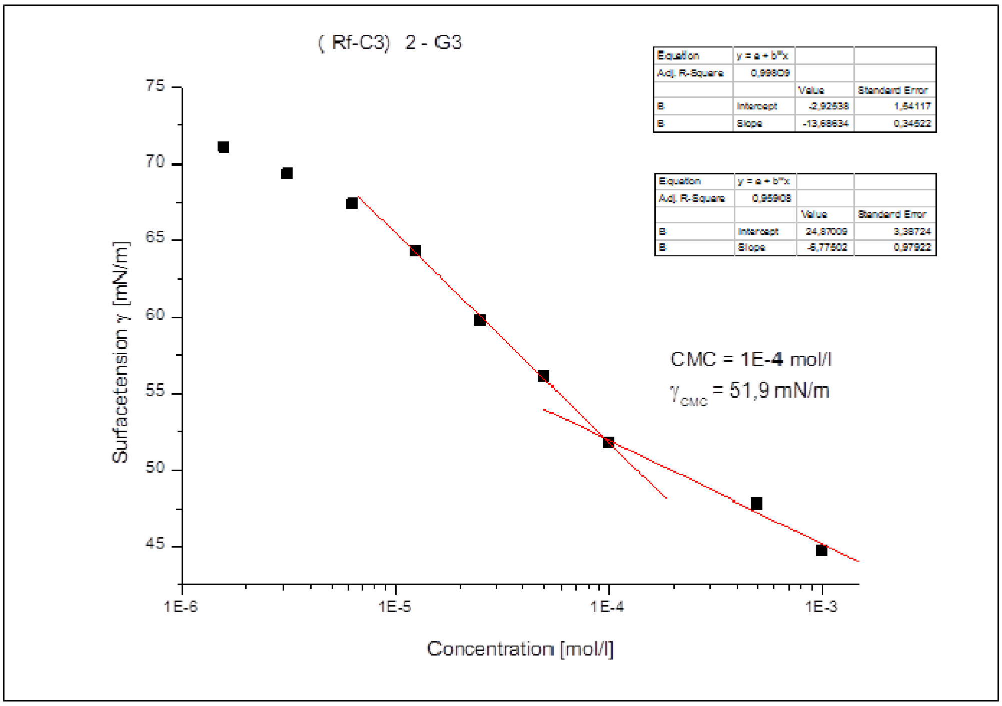


Figure S1. Plot of the surface tension γ of [G3] bi-perfluoro-tagged glycerol dendron in water versus the concentration.

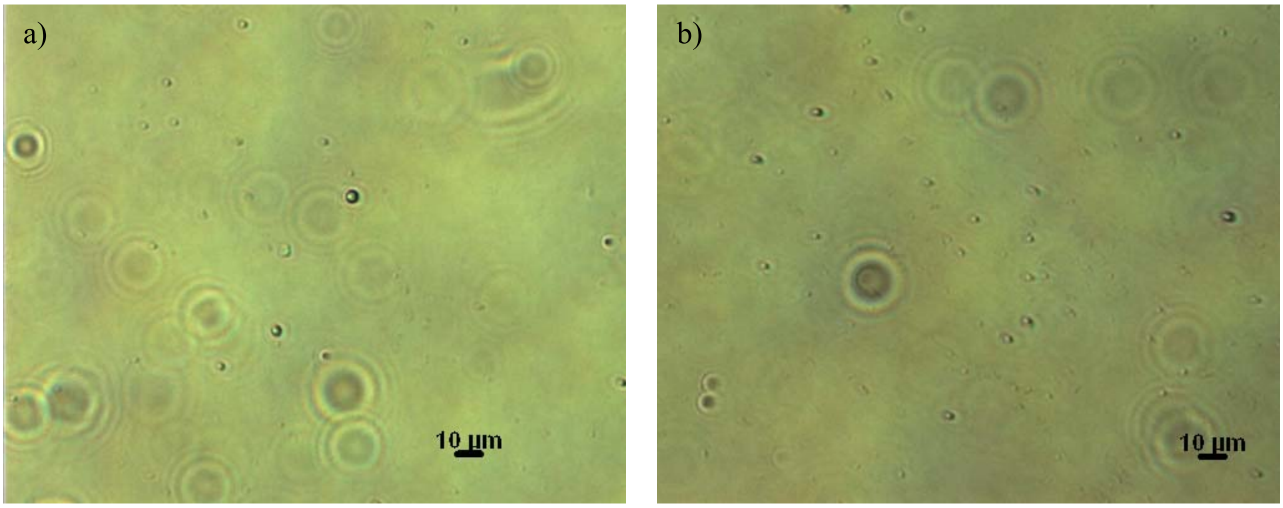


Figure S2. Optical microscopy pictures of micron-sized bubbles (Objective: LD EC-Epiplan-NEOFLUAR 20x/0.22DIC). a) Dendron-dendrimer (1:1) complex in water. b) Dendron-dendrimer (2:1) complex water.

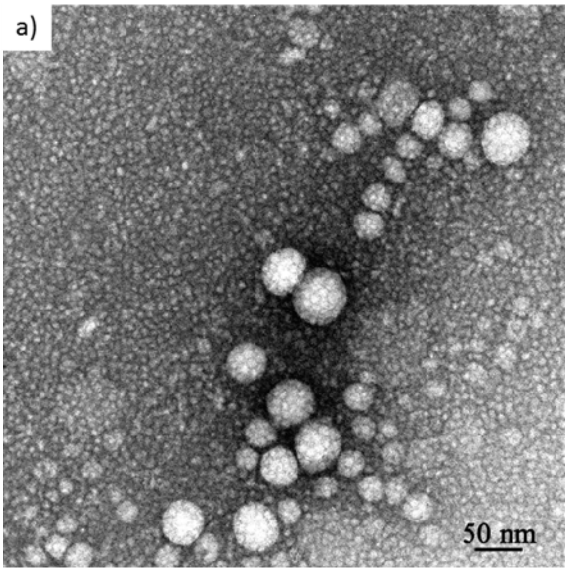


Figure 13. TEM images of dendron-dendrimer mixture (16:1) in water upon 20-fold dilution (based on the initial dendrimer concentration of $1.06*10^{-3}$ M) negatively stained with 4.5 % aqueous phosphotungstic acid/0.1 % trehalose.