Facile Synthesis of Amine-Terminated Aromatic Polyamide Dendrimer via Divergent Method

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Supporting Information
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**Measurement.** Infrared spectra were recorded on a Horiba FT-720 spectrophotometer. $^1$H and $^{13}$C NMR spectra were obtained on a BRUKER DPX-300 spectrometer at 300 and 75 MHz, respectively. Thermal analysis was performed on a Seiko EXSTAR 6000 TG/DTA 6300 thermal analyzer at a heating rate of 10 °C/min for thermogravimetry (TG) and differential thermal analysis (DTA), and a Seiko EXSTAR 6000 DSC 6200 at a heating rate of 10 °C/min for differential scanning calorimetry (DSC) under nitrogen. Matrix-assisted laser desorption ionization with time of flight (MALDI-TOF) mass spectrum of NH$_2$-G2D was obtained on a Kratos Kompact MALDI instrument operated in linear detection mode to generate positive ion spectra using dithranol as a matrix, N, N-dimethylformamide (DMF) as a solvent, and sodium trifluoroacetate as an additive agent. For CF$_3$-G3D and CF$_3$-G4D analyses, BRUKER DALTONICS autoflex instrument was used in reflector detection mode to generate positive ion spectra using dithranol as a matrix, tetrahydrofuran (THF) as a solvent, and sodium trifluoroacetate as an additive agent. Number- and weight-average molecular weights ($M_n$ and $M_w$) were determined by a gel permeation chromatograph (GPC) on a Jasco co-2065 GPC system equipped with polystyrene gel columns (TSK GElS, GMH$_{HR}$-M and GMH$_{HR}$-L) eluted with DMF containing 0.01 M of lithium bromide at a flow rate of 1.0 ml/min and calibrated by standard polystyrene samples.
**Materials.** *N*-Methyl-2-pyrrolidinone (NMP) was distilled under reduced pressure over calcium hydride and then stored under nitrogen. THF was dried over sodium and distilled before use under nitrogen. *p*-Phenylenediamine was purchased from Kanto Kagaku Co. and used as received. The other reagents and solvents were obtained commercially and used as received.

**Synthesis of 3,5-bis(trifluoroacetamido)benzoic acid**

To a solution of 3,5-diaminobenzoic acid (12.2 g, 80.0 mmol) in THF (100 ml) was added trifluoroacetic anhydride (54.6 g, 260 mmol) at 0 °C under nitrogen, and stirred at the temperature for 10 min, subsequently 25 °C for 3 h. Then, water (100 ml) was added and the resultant solution was stirred for 6 h at the temperature. The reaction mixture was extracted with diethyl ether. The organic layer was washed with water several times, dried over MgSO₄, and filtered. The filtrate was evaporated, and the residue was recrystallized from acetonitrile and dried under reduced pressure at 120 °C to give pale brown plates (94% yield).

Mp (DTA): 262 °C. IR (KBr): 713, 1168 (C-F), 1570, 1616 (Ar-H), 1716 (C=O), 2500~3300 (O-H), and 3313 cm⁻¹ (N-H). ¹H NMR (DMSO, 40 °C): δ = 8.12 (d, 2H),
8.39 (t, 1H), 11.46 (s, 2H). \(^{13}\)C NMR (CDCl\(_3\)): \(\delta = 115.8\) (q, \(J = 286.7\) Hz), 117.3, 118.9, 132.4, 137.4, 155.0 (q, \(J = 37.0\) Hz), and 166.5 ppm.

**Synthesis of 3,5-bis(trifluoroacetamido)benzoyl chloride (1)**

3,5-Bis(trifluoroacetamido)benzoic acid (10.0 g, 29.1 mmol) was refluxed in 100 ml of thionyl chloride for 6 h under nitrogen. The thionyl chloride was distilled off, and the residue was dissolved in tetrachloroethane at 100 °C and subsequently cooled to 20 °C to be recrystallized. The precipitate was filtrated and washed with hexane, followed by recrystallization again from dehydrated chloroform. The product was filtered and dried at 60 °C under reduced pressure to give slightly yellow needles (55% yield).

Mp: 145-147 °C. IR (KBr): 702, 1188 (C-F), 1022 (C-Cl), 1562, 1616 (Ar-H), 1716 (C=O), and 3286 cm\(^{-1}\) (N-H). \(^1\)H NMR (CDCl\(_3\), 25 °C): \(\delta = 8.19\) (d, 2H), 8.30 (s, 2H), 8.45 (t, 1H). Anal. Calcd for C\(_{11}\)H\(_5\)Cl\(_6\)F\(_6\)N\(_2\)O\(_3\): C, 36.43%; H, 1.39%; N, 7.73%. Found: C, 36.31%; H, 1.64%; N, 7.51%

**Synthesis of G1 dendrimer (NH\(_2\)-G1D)**

To a solution of \(p\)-phenylenediamine (0.108 g, 1.00 mmol) in NMP (2 ml) was added AB\(_2\)-building block 1 (0.798 g, 2.20 mmol) at 0 °C under nitrogen, and stirred at the
temperature for 5 min, followed by 25 °C for 1 h. Then, water (10 mg) was added, after which stirring was continued for 1 h at 50 °C. The resultant solution was treated with hydrazine monohydrate (0.600 g, 12.0 mmol) for another 1 h at the temperature. The reaction mixture was poured into 2 wt% of NaHCO₃ aq, subsequently the precipitate was filtered and dried at 120 °C under reduced pressure to give white solid (>99% yield).

Mp (DTA): 341 °C. IR (KBr): 1519, 1554, 1620 (Ar-H), 1639 (C=O), and 1597, 3409 cm⁻¹ (N-H). ¹H NMR (DMSO, 40 °C): δ = 4.83 (s, 8H), 6.00 (t, 2H), 6.31 (d, 4H), 7.64 (s, 4H), 9.76 (s, 2H). ¹³C NMR (DMSO, 40 °C): δ = 102.2, 102.3, 120.1, 134.9, 136.8, 148.9, and 166.8 ppm. Anal. Calcd for C₉₀H₈₀N₆O₂: C, 63.8%; H, 5.36%; N, 22.33%. Found: C, 64.12%; H, 5.64%; N, 22.37%.

Synthesis of G2 dendrimer (NH₂-G2D)

To a solution of NH₂-G1D (0.0941 g, 0.250 mmol) in NMP (1 ml) was added AB₂-building block 1 (0.399 g, 1.1 mmol) at 0 °C under nitrogen, and stirred at the temperature for 5 min, followed by 25 °C for 1 h. Then, water (5 mg) was added, after which stirring was continued for 1 h at 50 °C. The resultant solution was treated with hydrazine monohydrate (0.300 g, 12.0 mmol) for another 1 h at the temperature. The
reaction mixture was poured into 2 wt% of NaHCO₃ \textit{aq}, subsequently the precipitate was filtered and dried at 120 °C under reduced pressure to give white solid (94% yield).

Mp (DTA): 371 °C. IR (KBr): 1512, 1554 (Ar-H), 1639 (C=O), and 1601, 3325 cm⁻¹ (N-H). \(^1\)H NMR (DMSO, 40 °C): \(\delta = 4.85\) (s, 16H), 6.03 (t, 4H), 6.37 (d, 8H), 7.73 (s, 4H), 7.91 (d, 4H), 8.35 (t, 2H), 10.01 (s, 4H) 10.20 (s, 2H). \(^1^3\)C NMR (DMSO, 40 °C): \(\delta = 102.5, 114.9, 115.4, 120.4, 134.9, 136.0, 136.5, 139.5, 148.9, 165.8\) and 167.1 ppm.


**Synthesis of G3 dendrimer (NH₂-G3D)**

To a solution of NH₂-G₂D (0.114 g, 0.125 mmol) in NMP (1.33 ml) was added AB₂-building block 1 (0.399 g, 1.1 mmol) at 0 °C under nitrogen, and stirred at the temperature for 5 min, followed by 25 °C for 1 h. Then, water (5 mg) was added, after which stirring was continued for 1 h at 50 °C. The resultant solution was treated with hydrazine monohydrate (0.300g, 12.0 mmol) for another 3 h at the temperature. The reaction mixture was poured into 2 wt% of NaHCO₃ \textit{aq}, subsequently the precipitate was filtered and dried at 120 °C under reduced pressure to give white solid (95% yield).
intermediate, **CF$_3$-G3D**, was isolated to obtain the MALDI-TOF MS spectrum. The coupling reaction of **NH$_2$-G2D** and **I** was carried out to yield **CF$_3$-G3D** using the same protocol as described above. The reaction solution was poured into 1 wt% of NaHCO$_3$aq, and then the precipitate was filtered and dried at 80 °C under reduced pressure. The resulting product was analyzed by MALDI-TOF MS spectroscopy.

T$_g$ (glass-transition temperature): 276 °C. IR (KBr): 1543 (Ar-H), 1639 (C=O), and 1601, 3332 cm$^{-1}$ (N-H). $^1$H NMR (DMSO, 40 °C): $\delta$ = 4.74 (s, 32H), 6.06 (t, 8H), 6.42 (d, 16H), 7.76 (s, 4H), 7.98 (d, 8H), 8.01 (d, 4H), 8.35 (t, 4H), 8.46 (t, 2H), 9.89 (s, 8H), 10.16 (s, 2H), 10.33 (s, 4H). $^{13}$C NMR (DMSO, 40 °C): $\delta$ = 102.6, 102.7, 115.1, 115.3, 115.7, 120.6, 134.9, 135.7, 136.2, 136.5, 139.3, 139.5, 148.8, 165.6, 166.1 and 167.0 ppm.

Anal. Calcd for C$_{104}$H$_{92}$N$_3$O$_{14}$ 3.77H$_2$O: C, 60.81%; H, 4.88%; N, 20.46%. Found: C, 60.51%; H, 4.58%; N, 20.51%. Calcd. for **CF$_3$-G3D**: [M]$^+$ m/z = 3520.5. Found: MALDI-TOF-MS: [M+Na]$^+$ = 3543.5 and [M+2Na-H]$^+$ = 3565.5.

**Synthesis of G4 dendrimer (NH$_2$-G4D)**

To a solution of **NH$_2$-G3D** (0.124 g, 0.0625 mmol) in NMP (1.33 ml) was added AB$_2$-building block **I** (0.399 g, 1.1 mmol) at 0 °C under nitrogen, and stirred at the
temperature for 5 min, followed by 25 °C for 1 h. Then, water (5 mg) was added, after which stirring was continued for 1 h at 50 °C. The resultant solution was treated with hydrazine monohydrate (0.300g, 12.0 mmol) for another 3 h at the temperature. The reaction mixture was poured into 2 wt% of NaHCO₃aq, subsequently the precipitate was filtered and dried at 120 °C under reduced pressure to give white solid (95% yield). The intermediate, CF₃-G4D, was isolated to obtain the MALDI-TOF MS spectrum. The coupling reaction of NH₂-G3D and 1 was carried out to yield CF₃-G4D using the same protocol as described above. The reaction solution was poured into 1 wt% of NaHCO₃aq, and then the precipitate was filtered and dried at 80 °C under reduced pressure. The resulting product was analyzed by MALDI-TOF MS spectroscopy.

Tₚ : 300 °C. IR (KBr): 1543 (Ar-H), 1639 (C=O), and 1601, 3321 cm⁻¹ (N-H). ¹H NMR (DMSO, 40 °C): δ = 4.75 (s, 64H), 6.04 (t, 16H), 6.41 (d, 32H), 7.75 (s, 4H), 7.98 (d, 16H), 8.03 (d, 4H), 8.06 (d, 8H), 8.37 (t, 8H), 8.46-8.52 (m, 6H), 9.90 (s, 16H), 10.17 (s, 2H), 10.35 (s, 8H), 10.44 (s, 4H). ¹³C NMR (DMSO, 40 °C): δ = 102.6, 102.7, 115.1, 115.4, 115.7, 120.6, 134.9, 135.7, 136.0, 136.2, 136.4, 139.3, 139.5, 148.8, 165.5, 166.0, 166.1 and 167.0 ppm. Anal. Calcd for C₂₁₆H₁₈₈N₆₂O₃₀ 8.88H₂O: C, 60.44%; H, 4.83%; N, 20.23%. Found: C, 60.45%; H, 4.84%; N, 20.24%. Calcd. for CF₃-G4D: [M]⁺ m/z = 7204.5. Found: MALDI-TOF-MS: [M+Na]⁺ = 7228.3.
This signal attributes to the CF$_3$-G3D that lost one trifluoroacetyl group probably because of partial deprotection during ionization or purification process.

$[\text{M+Na}]^+$; 3543.5

$[\text{M+2Na-H}]^+$; 3565.5

Figure 11S.
Figure 13S.
Figure 15S.