Electronic Supplementary Information

for

Supramolecular Self-Assembly of Dendrimers Containing Orthogonal Binding Motifs

Felix Grimm, Kristine Hartnagel, Florian Wessendorf and Andreas Hirsch*

Department of Chemistry and Pharmacy & Interdisciplinary Center for Molecular Materials (ICMM) Friedrich-Alexander Universität Erlangen-Nürnberg, Henkestrasse 42, 91054, Erlangen, Germany.

Experimental Section

All chemicals were obtained from Sigma-Aldrich and Acros Organics or were prepared according to known literature procedures. 2,2'-Bipyridinyl-4,4'-dicarboxylic acid[1], 5-amino-N,N'-bis[6-(3,3-dimethylbutyrylamino)pyridin-2-yl]isophthalamide[2] (Hamilton receptor **4**) and di-*tert*-butyl 4-(2-*tert*-butoxycarbonyl)-ethyl-4-aminoheptanedioate[3] were prepared as described in literature, the synthesis of 1-(5-Carboxypentyl)-1,3,5-triazin-2,4,6-trion[4] and the end caps **8**[4] and **9**[5] was previously reported by our group. ^{1}H and ^{13}C NMR spectra were recorded on Bruker Avance 300, JEOL JNM EX 400, JEOL JNM GX 400 and JEOL A 500. Mass spectra were measured with a Micromass Lab Spec (FAB) on a Finnigan MAT 900 spectrometer with 3-nitrobenzylalcohol as the matrix, MALDI-TOF measurements were made with an AXIMA-CFR plus instrument (Kratos Analytical). Elementary analysis succeeded by combustion and gas chromatographical analysis with an EA 1110 CHNS analyser (CEInstruments).

4,4'-Dicarboxysuccinimidyl-2,2'-bipyridine (2)

2,2'-Bipyridinyl-4,4'-dicarboxylic acid (1.00 g, 4.1 mmol) and N-hydroxysuccinimid (0.95 g, 8.2 mmol) were dissolved in dry DMF (40 mL). Dicyclohexylcarbodiimide (1.70 g, 8.2 mmol) dissolved in DMF (10 mL) was added drop wise. The solution was allowed to stir for 12 h and then filtered to remove the dicyclohexylurea by-product. Solvent was removed by vacuum, and the resulting solid recrystallized with dichloromethane to yield the disuccinimidyl ester **2** (1.25 g; 2.8 mmol, 69 %). **^{1}H-NMR** (300 MHz, $CDCl_3$): δ = 3.0 (s, 8H, CH_2), 5.3 (s, 2H, NH), 8.0 (d, ^{3}J = 4.9 Hz, 2H, H_{bpy}), 8.95 (s, 2H, H_{bpy}), 9.13 (d, ^{3}J = 4.9 Hz, 2H, H_{bpy}) ppm.

4,4'-[Bis(6-hexanoic acid)amide]-2,2'-bipyridine (3)

6-Aminohexanoic acid (1.080 g, 8.20 mmol) was suspended in dry DMF (50 mL). Through a

dropping funnel, 4,4'-dicarboxysuccinimidyl-2,2'-bipyridine **2** (1.199 g, 2.74 mmol) in dry DMF was added and the resulting suspension stirred for 24 h at RT. The solvent was removed under reduced pressure and the residue washed with water, MeOH and diethyl ether. Drying yields 801 mg (1.70 mmol, 62 %) of the desired product **3**. **^{1}H-NMR** (300 MHz, DMSO-d_6): δ = 1.34 (m, 4H, 2 x CH_2), 1.55 (m, 8H, 4 x CH_2), 2.22 (t, ^{3}J = 7.2 Hz, 4H, CH2COO), 3.31 (m, 4H, C*H*$_2$NH), 7.83 (d, ^{3}J = 4.9 Hz, 2H, H_{bpy}), 8.78 (s, 2H, H_{bpy}), 8.85 (d, ^{3}J = 4.9 Hz, 2H, H_{bpy}), 8.9 (br, 2H, NH) ppm. **^{13}C-NMR** (75 MHz, DMSO-d_6): δ = 24.3, 26.1, 28.7 (CH_2), 33.7 (CH_2COO), 39.3 (CH_2NH), 118.3 (5-bpy), 122.0 (3-bpy), 143.1 (4-bpy), 150.0 (6-bpy), 155.6, (2-bpy), 164.5 (C=O), 174.5 (C=O) ppm.

4,4-{Di(6-aminohexanoic acid)-5-amino-N,N'-bis[6-(3,3-dimethylbutyricamino)pyridin-2-yl]isophthalamide)-amide}-2,2'-bipyridine (AB_2 building block 1)

4,4'-[Bis(6-hexanoic acid)amide]-2,2'-bipyridine **3** (420 mg, 0.89 mmol) was suspended in dry DMF (50 mL). Dicyclohexylcarbodiimide (553 mg, 2.67 mmol), dimethylaminopyridine (327 mg, 2.67 mmol) and 1-hydroxybenzotriazole (362 mg, 2.67 mmol) were added under vigorous stirring. After 30 minutes, a solution of 5-amino-N,N'-bis[6-(3,3-dimethylbutyrylamino)pyridin-2-yl]isophthalamide **4** (1.50 g, 2.67 mmol) in dry dichloromethane (50 mL) was added. The mixture was stirred at RT for 3 days and than another 2 days at 55°C. After removal of the solvent by vacuum, the product was purified via column chromatography (silica, CH_2Cl_2/MeOH 99:1, gradient slope to CH_2Cl_2/MeOH 95:5, silica) and recrystallized from acetone to yield 729 mg (0.47 mmol, 53 %) of **1**. **^{1}H-NMR** (400 MHz, DMSO-d_6): δ = 1.01 (s, 36H, CH_3), 1.40 (m, 4H, CH_2), 1.61 (m, 4H, CH_2), 1.68 (m, 4H, CH_2), 2.30 (s, 8H, C*H*$_2$C(CH_3)$_3$), 2.39 (m, 4H, CH_2CONH-Ar), ca. 3.3 (m, 4H; C*H*$_2$NH), 7.75-7.90 (m, 14H, $H_{Py,}$ H_{bpy}), 8.20 (s, 2H, H_{Ar}), 8.36 (s, 4H, H_{Ar}), 8.78 (s, 2H, H_{bpy}), 8.84 (d, $^3J_{H,H}$ = 5.5 Hz, 2H, H_{bpy}), 9.0 (br, 2H, NH), 10.0 (br, 4H, NH), 10.3 (br, 2H, NH), 10.4 (br, 4H, NH) ppm. **^{13}C-NMR** (100 MHz, DMSO-d_6): δ = 24.7, 26.0, 28.8 (CH_2), 29.5 (CH_3), 30.8 (*C*(CH_3)$_3$), 34.5 (*C*H_2CONH-Ar), ca. 40 (CH_2NH), 49.0 (*C*H_2C(CH_3)$_3$), 110.0, 110.4 (CH_{Pyr}), 118.2 (CH_{bpy}), 121.4 (CH_{Ar}), 121.7 (CH_{bpy}), 121.9 (CH_{Ar}), 134.8, 139.9 (*q*C_{Ar}), 140.1 (CH_{Pyr}), 143.1 (*q*C_{bpy}), 150.0 (CH_{bpy}), 150.1, 150.6 (*q*C_{Pyr}), 155.6 (*q*C_{bpy}), 164.5, 165.2, 170.9, 171.8 (C=O) ppm. **MS (FAB)**: *m/z* : 1554 $[MH]^+$. **UV/vis (CH_3CN):** λ_{max} = 299 nm. **Elemental analysis:** found: C, 62.7; H, 7.0; N, 15.0. Calc for $C_{86}H_{112}N_{18}O_{16}$ (**1** · 2 H_2O · 2 MeOH): C, 62.5; H, 6.8; N, 15.2 %.

$[Ru(AB_2)_3](PF_6)_2$ (5)

$RuCl_3$ · x H_2O (19 mg, 74 µmmol) and 4 equivalents of AB_2 branching unit **1** (459 mg, 29

µmol) were dissolved in a mixture of dry methanol-chloroform (1:1, 40 mL) under inert-gas atmosphere and refluxed for 20 d. $AgPF_6$ (38 mg, 128 µmol) was added and the mixture stirred for another 24 h at rt. After removal of AgCl by centrifugation, the solvents were removed under reduced pressure and the crude product purified by HPLC (Nucleosil, CH_2Cl_2/MeOH 97:3). Recrystallization from acetone/diethyl ether yielded 207 mg (41 µmol, 55 %). **^{1}H-NMR** (400 MHz, DMSO-d_6): δ = 1.00 (s, 108H, CH_3), 1.41 (m, 12H, CH_2), 1.64 (m, 12H, CH_2), 1.70 (m, 12H, CH_2), 2.32 (s, 24H, C*H*$_2$C(CH_3)$_3$), 2.40 (m, 12H, CH_2CONH-Ar), 3,35 (m, 12H; C*H*$_2$NH), 7.84-7.87 (m, 42H, $H_{Py,}$ H_{bpy}), 8.27 (s, 6H, H_{Ar}), 8.39 (s, 12H, H_{Ar}), 8.82 (s, 6H, H_{bpy}), 8.87 (d, $^3J_{H,H}$ = 5.5 Hz, 6H, H_{bpy}) ppm. **^{13}C-NMR** (100 MHz, DMSO-d_6): δ = 24.2, 25.6, 28.2 (CH_2), 29.0 (CH_3), 31.1 (*C*(CH_3)$_3$), 35.8 (*C*H_2CONH-Ar), 38.8 (CH_2NH), 48.7 (*C*H_2C(CH_3)$_3$), 109.7, 109.9 (CH_{Pyr}), 117.8 (CH_{bpy}), 121.4 (CH_{Ar}), 121.6 (CH_{bpy}), 122.5 (CH_{Ar}), 134.6, 139.8 (*q*C_{Ar}), 143.2 (*q*C_{bpy}), 139.9 (CH_{Pyr}), 149.7 (CH_{bpy}), 150.2, 150.6 (*q*C_{Pyr}), 155.6 (*q*C_{bpy}), 164.5, 165.4, 171.1, 172.0 (C=O) ppm. **MS (MALDI-TOF, matrix: dithranol)**: *m/z* : 4762 $[Ru(AB_2)_3]^+$. **UV/vis ($CHCl_3$):** λ_{max} = 291, 472 nm.

Di-*tert*-butyl 4-(3-*tert*-butoxy-3-oxopropyl)-4-(6-(2,4,6-trioxo-1,3,5-triazinan-1-yl)hexanamido)heptanedioate (end cap 7)

200 mg of 1-(5-Carboxypentyl)-1,3,5-triazin-2,4,6-trion (0.85 mmol) were suspended in 50 ml dry dichloromethane. After cooling to 0 °C, 104 mg (0.85 mmol) dimethylaminopyridine, 115 mg (0.85 mmol) 1-hydroxybenzotriazole and 164 mg (0.85 mmol) *N*-(3-Dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride were added. After stirring for 30 min at 0 °C, 335 mg of di-*tert*-butyl 4-(2-*tert*-butoxycarbonyl)-ethyl-4-aminoheptanedioate were added to the solution and stirring was continued for 3d at rt. After removal of the solvent by vacuum, the product was purified via column chromatography (silica, EtOAc/MeOH 90:10) to yield 250 mg (0.39 mmol, 46%) of **7** as colorless solid. **^{1}H-NMR** (300 MHz, $CDCl_3$): δ = 1.31 (m, 2H; CH_2), 1.37 (s, 27H; CH_3), 1.63 (m, 2H; CH_2), 1.65 (m, 2H; CH_2), 1.95 (m, 6H; *CH*$_2$$CH_2CO_2$^{t}Bu), 2.14 (t, ^{3}J = 7.3 Hz, 2H; CH_2CONH), 2.21 (t, ^{3}J = 7.2 Hz; CH_2*CH*$_2$$CO_2$^{t}Bu), 3.84 (t, ^{3}J = 6.9 Hz, 2H; CH_2N), 6.09 (s, 1H, NH), 9.72 (s, 2H, CO-NH-CO) ppm. **^{13}C-NMR** (75 MHz, $CDCl_3$): δ = 30.0 (CH_2), 26.7, 28.1, 29.1, 31.8, 31.9, 39.0, 43.2 (CH_2), 59.3 (NH*C*(CH_2R)$_3$), 83.0 ppm (CMe_3), 149.9, 151.5 (NH*C*ONH), 174.5, 175.3 (C=O) ppm. **MS (FAB)**: *m/z*: 641 $[MH]^+$, 472 [M-3x*t*-Bu]$^+$, 231 $[C(CH_2CH_2CO_2H]^+$. **Elemental analysis:** found: C, 58.1; H, 8.2; N, 8.7. Calc for $C_{31}H_{52}N_4O_{10}$: C, 58.1; H, 8.2; N, 8.5 %.

Literature

1. N. Garelli and P. Vierling, *Journal of Organic Chemistry*, 1992, **57**, 3046-3051.
2. A. Dirksen, U. Hahn, F. Schwanke, M. Nieger, J. N. H. Reek, F. Vögtle and L. De Cola, *Chem. Eur. J.*, 2004, **10**, 2036-2047.
3. G. R. Newkome, R. K. Behera, C. N. Moorefield and G. R. Baker, *Journal of Organic Chemistry*, 1991, **56**, 7162-7167.
4. K. Hager, A. Franz and A. Hirsch, *Chem. Eur. J.*, 2006, **12**, 2663-2679.
5. F. Wessendorf, J.-F. Gnichwitz, G. H. Sarova, K. Hager, U. Hartnagel, D. M. Guldi and A. Hirsch, *Journal of the American Chemical Society*, 2007, **129**, 16057-16071.