Supplementary material (ESI) for Journal of Materials Chemistry

Electronic Supporting Information for:

Synthesis, characterisation and chiroptical properties of 'click'able polyisocyanopeptides

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Compounds

Boc-L-alanine prop-2-ynol ester (L-BAPE) 6

Boc-L-alanine-OH (4.40 g, 23.3 mmol) and 2-propynol (1.54 g, 27.5 mmol, 1.2 equiv.) were dissolved in CH_2Cl_2 (300 mL). To this solution diisopropylethylamine (DIPEA; 4.3 mL, 26 mmol, 1.1 equiv.), 1-hydroxybenzatriazole (HOBt; 3.97 g, 25.9 mmol, 1.1 equiv.) and finally 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC; 4.9 g, 25.6 mmol, 1.1 equiv.) were added. After stirring for 10 hours the solvent was evaporated *in vacuo* and the product was redissolved in $CHCl_3$ (200 mL). This solution was subsequently washed with an aqueous 10% (w/w) citric acid solution (2 × 200 mL), H_2O (200 mL), an aqueous 10 % (w/w) sodium carbonate solution (2 × 200 mL) and H_2O (200 mL). The organic layer was dried (Na_2SO_4), concentrated and subjected to column chromatography (2% MeOH in $CHCl_3$), yielding 92% of 6 as a colorless oil. $[\alpha]_D$ –17 (*c* 0.8 in $CHCl_3$). ^{1}H NMR (δ ppm, $CDCl_3$): 5.03 (s, 1H, NH), 4.71 (m, 2H, C≡CC*H*$_2$), 4.32 (m, 1H, CH Ala), 2.47 (t, 1H, HC≡C, *J* 2.4), 1.41 (s, 9H, C(CH$_3$)$_3$), 1.38 (d, 3H, CH$_3$ Ala, *J* 7.2). ^{13}C NMR (δ ppm, $CDCl_3$): 172.3, 154.8 (C=O), 80.0 (*C*(CH$_3$)$_3$, 77.2 (HC≡*C*CH$_2$), 75.4 (H*C*≡CCH$_2$), 52.8 (CH Ala), 49.3 (HC≡C*C*H$_2$), 28.6 (C(*C*H$_3$)$_3$), 18.6 (CH$_3$ Ala). FT-IR (cm^{-1}, ATR): 3299 (NH), 2128 (C≡C), 1748 (C=O ester), 1701 (Amide I), 1506 (amide II). MS-CI: m/z = 228 [M+H]$^+$. HRMS for $C_{11}H_{18}NO_4$: Calcd 228.1236. Found: 228.1230.

Boc-L-alanyl-L-alanine prop-2-ynol ester (L,L-BAAPE)

L-BAPE (2.03 g, 8.9 mmol) was dissolved in HCl-saturated ethyl acetate (100 mL). The mixture was stirred for 5 hours after which the reaction mixture was concentrated to a small volume, *t*-BuOH/CH_2Cl_2 was added and evaporated under reduced pressure twice, to remove the excess of HCl. The resulting L-alanine prop-2-ynol ester HCl salt was dissolved in CH_2Cl_2 (200 mL). To this solution Boc-L-alanine-OH (1.88 g, 9.9 mmol, 1.1 equiv.), DIPEA (3.3 mL, 20 mmol, 2.2 equiv.), HOBt (1.52 g, 9.9 mmol, 1.1 equiv.) and finally EDC (1.92 g, 10.0 mmol, 1.1 equiv.) were added. After stirring for 36h the solvent was evaporated *in vacuo* and the product was redissolved in $CHCl_3$ (150 mL). This solution was washed with an aqueous 10% (w/w) citric acid solution (2 × 150 mL), H_2O (150 mL), an aqueous 10 % (w/w) sodium carbonate solution (2 × 150 mL) and H_2O (150 mL). The organic layer was dried (Na_2SO_4), concentrated and subjected to column chromatography (2% MeOH in $CHCl_3$), yielding 1.9 g of **L,L-BAAPE** in 72% yield as a white powder. Mp: 84 °C. $[\alpha]_D$ –41 (*c* 0.9 in $CHCl_3$). ^{1}H NMR (δ ppm, $CDCl_3$): 7.07 (s, 1H, NH), 5.38 (d, 1H, NH, *J* 7.5), 4.67 (m, 2H, HC≡CC*H*$_2$), 4.52 (quintet, 1H, CH Ala *J* 7.2), 2.45 (t, 1H, HC≡C, *J* 6.0), 1.36 (s, 9H, C(CH_3)$_3$), 1.29 (m, 6H, CH_3 Ala). ^{13}C NMR (δ ppm, $CDCl_3$): 172.7, 171.9, 155.5 (C=O), 79.9 (*C*(CH$_3$)$_3$, 77.2 (HC≡*C*CH$_2$), 75.5 (H*C*≡CCH$_2$), 52.8 (CH Ala), 49.8 (HC≡C*C*H$_2$), 47.9 (CH Ala), 28.3 (C(*C*H$_3$)$_3$), 18.5, 17.7 (CH_3 Ala). FT-IR (cm^{-1}, ATR): 3270 (NH), 2135 (C≡C), 1738 (C=O ester), 1679, 1653 (Amide I), 1555, 1518 (amide II). MS-CI: m/z = 299 $[M+H]^+$. HRMS for $C_{14}H_{23}N_2O_5$: Calcd 299.1607. Found: 299.1595.

Boc-D-alanyl-L-alanine prop-2-ynol ester (D,L-BAAPE) 7

Starting from **6** and Boc-D-alanine-OH, following the same procedure as for **L,L-BAAPE**, **D,L-BAAPE** was obtained as a viscous colorless oil (yield 46%).$[\alpha]_D$ +24 (*c* 1.3 in $CHCl_3$). ^{1}H NMR (δ ppm, $CDCl_3$): 6.76 (s, 1H, NH), 4.98 (s, 1H, NH), 4.72 (m, 2H, HC≡CC*H*$_2$), 4.59 (quintet, 1H, CH Ala *J* 7.2), 2.48 (t, 1H, HC≡C, *J* 2.4), 1.44 (s, 9H, C(CH_3)$_3$), 1.42 (d, 4H, CH_3 Ala, *J* 7.2), 1.35 (d, 4H, CH_3 Ala, *J* 6.9). ^{13}C NMR (δ ppm, $CDCl_3$): 172.4, 172.2, 155.7 (C=O), 80.5 (*C*(CH$_3$)$_3$), 77.2 (HC≡*C*CH$_2$), 75.5 (H*C*≡CCH$_2$), 52.9 (CH Ala), 50.1 (HC≡C*C*H$_2$), 48.0 (CH Ala), 28.4 (C(*C*H$_3$)$_3$),

18.2, 17.3 (CH_3 Ala). FT-IR (cm^{-1}, ATR): 3297 (NH), 2128 (C≡C), 1747 (C=O ester), 1700, 1660 (Amide I), 1512 (br, amide II). MS-CI: m/z = 299 $[M+H]^+$. HRMS for $C_{14}H_{23}N_2O_5$: Calcd 299.1607. Found: 299.1600.

Boc-L-alanine-(3-trimethylsilyl) prop-2-ynol ester (L-BAPE-TMS)

Following a similar procedure as for **L-BAPE**, **L-BAPE-TMS** was obtained in 77% yield as a colorless oil. $[\alpha]_D$ –16 (*c* 0.8 in $CHCl_3$). ^1H NMR (δ ppm, $CDCl_3$): 5.03 (s, 1H, NH), 4.71 (d, 2H, HC≡CC*H*$_2$, *J* 1.8), 4.31 (m, 1H, CH Ala), 1.42 (s, 9H, $C(CH_3)_3$), 1.38 (d, 3H, CH_3 Ala J =7.2), 0.15 (s, 9H, Si-CH_3). ^{13}C NMR (δ ppm, $CDCl_3$): 172.7, 155.2 (C=O), 98.6 (C≡*C*CH_2), 92.7 (*C*≡CCH_2), 80.0 (*C*(CH_3)$_3$), 53.6 (C≡C*C*H_2), 49.3 (CH Ala), 28.4 (C(*C*H_3)$_3$), 18.6 (CH_3 Ala), 0.1 (Si-CH_3). FT-IR (cm^{-1}, ATR): 3277 (NH), 2187 (C≡C), 1747 (C=O ester), 1714 (Amide I), 1505 (amide II), 1250 (Si-CH_3). MS-ESI m/z = 322 $[M+Na]^+$. HRMS for $C_{14}H_{25}NO_4SiNa$: Calcd 322.1434. Found: 322.1450.

Boc-D-alanyl-L-alanine-(3-trimethylsilyl) prop-2-ynol ester (D,L-BAPE-TMS)

Following a similar procedure as for **D,L-BAAPE**, **D,L-BAAPE-TMS** was obtained as a colorless oil in 75% yield. $[\alpha]_D$ +28 (*c* 1.2 in $CHCl_3$).^1H NMR (δ ppm, $CDCl_3$): 7.05 (s, 1H, NH), 5.40 (s, 1H, NH), 4.63 (d, 2H, HC≡CC*H*$_2$, *J* 2.0), 4.52 (quintet, 1H, CH Ala, *J* 7.3), 1.35 (m, 12H, $C(CH_3)_3$), CH_3 Ala), 1.26 (d, 3H, CH_3 Ala, J =7.1), 0.07 (s, 9H, Si-CH_3). ^{13}C NMR (δ ppm, $CDCl_3$): 172.6, 172.1, 155.5 (C=O), 98.4 (C≡*C*CH_2), 92.5 (*C*≡CCH_2), 79.9 (*C*(CH_3)$_3$), 53.5 (C≡C*C*H_2), 49.9, 47.9 (CH Ala), 28.3 (C(*C*H_3)$_3$), 18.3, 17.9 (CH_3 Ala), –0.4 (Si-CH_3). MS-ESI m/z = 393 $[M+Na]^+$. HRMS for $C_{17}H_{30}N_2O_5SiNa$: Calcd 393.1826. Found: 393.1822. FT-IR (cm^{-1}, ATR): 3313 (br,NH), 2186 (C≡C), 1747 (C=O ester), 1661 (Amide I), 1514 (amide II), 1250 (Si-CH_3).

Boc-L-alanine hept-6-ynol ester (L-BAHE)

Starting from Boc-L-alanine-OH and hept-6-ynol, **L-BAHE** was prepared following a similar procedure as for **L-BAPE**, with the exception that the product was purified by column chromatography (Heptane-EtOAc 7:3 v/v, followed by 2% MeOH in $CHCl_3$). **L-BAHE** was obtained as a colorless oil (yield 78%). $[\alpha]_D$ –4 (*c* 2.1 in $CHCl_3$). ^{1}H NMR (δ ppm, $CDCl_3$): 5.03 (d, 1H, NH, *J* 7.8), 4.28 (m, 1H, CH Ala), 4.13 (m, 3H, OCH_2, CH Ala), 2.19 (m, 2H, HC≡CC*H*$_2$), 1.93 (t, 1H, *H*C≡CCH_2, *J* 2.7), 1.65 (quintet, 2H, CH_2, *J* 7.2), 1.52 (m, 4H, CH_2), 1.42 (s, 9H, $C(CH_3)_3$), 1.36 (d, 3H, CH_3 Ala, *J* 7.2). ^{13}C NMR (δ ppm, $CDCl_3$): 173.5, 155.2 (C=O), 84.2 (C≡*C*CH_2), 80.0 (*C*$(CH_3)_3$), 68.6 (*C*≡CCH_2), 65.2 (OCH_2), 49.4 (CH Ala), 28.4 (C(*C*$H_3)_3$), 28.2, 28.1, 25.0, 18.9 (CH_2), 18.4 (CH_3 Ala). FT-IR (cm^{-1}, ATR): 3377, 3303 (NH), 2111 (C≡C), 1710 (br, C=O ester, amide I), 1510 (amide II). MS-ESI m/z = 306 $[M+Na]^+$. HRMS for $C_{15}H_{25}N_1O_4Na$: Calcd 306.1681. Found: 301.1701.

Boc-L-alanyl-L-alanine hept-6-ynol ester (L,L-BAAHE)

Following a similar procedure as for **L-BAPE**, **L,L-BAAHE** was obtained in 60% yield as a colorless oil.

$[\alpha]_D$ –18 (*c* 0.9 in $CHCl_3$). ^{1}H NMR (δ ppm, $CDCl_3$): 6.79 (s, 1H, NH), 5.18 (d, 1H, NH, *J* 7.8), 4.51 (quintet, 1H, CH Ala, *J* 7.2), 4.10 (m, 3H, OCH_2, CH Ala), 2.16 (m, 2H, HC≡CC*H*$_2$), 1.92 (t, 1H, *H*C≡CCH_2, *J* 2.7), 1.63 (quintet, 2H, CH_2, *J* 7.0), 1.49 (m, 4H, CH_2), 1.40 (s, 9H, $C(CH_3)_3$), 1.36 (d, 3H, CH_3 Ala, *J* 7.2), 1.32 (d, 3H, CH_3 Ala, *J* 7.0). ^{13}C NMR (δ ppm, $CDCl_3$, 50 M): 172.8, 172.4, 155.5 (C=O), 84.1 (C≡*C*CH_2), 80.0 (*C*$(CH_3)_3$), 68.6 (*C*≡CCH_2), 65.3 (OCH_2), 50.0, 48.1 (CH Ala), 28.4 (C(*C*$H_3)_3$), 28.1, 28.0, 24.9 (CH_2), 18.5 (CH_3 Ala), 18.4 (CH_2), 18.3 (CH_3 Ala). FT-IR (cm^{-1}, ATR): 3299 (NH), 2116 (C≡C), 1736 (C=O ester), 1661 (Amide I), 1519 (amide II). MS-ESI m/z = 377 $[M+Na]^+$. HRMS for $C_{18}H_{30}N_2O_5Na$: Calcd 377.2052 Found: 377.2040.

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Boc-D-alanyl-L-alanine hept-6-ynol ester (D,L-BAAHE)

Following a similar procedure as for **L-BAPE**, **D,L-BAAHE** was obtained in 75 % yield as a colorless oil. [α]D +28 (c 0.8 in CHCl3). 1H NMR (δ ppm, CDCl3): 6.82 (s, 1H, NH), 5.14 (d, 1H, NH, J 7.5), 4.51 (quintet, 2H, CH Ala, J 7.2), 4.12 (m, 3H, OCH2, CH Ala), 2.16 (m, 2H, HC≡CCH2), 1.91 (t, 1H, HC≡CCH2, J 2.7), 1.63 (quintet, 2H, CH2, J 6.9), 1.48 (m, 4H, CH2), 1.41 (s, 9H, C(CH3)3), 1.36 (d, 3H, CH3 Ala, J 7.2), 1.32 (d, 3H, CH3 Ala, J 7.2). 13C NMR (δ ppm, CDCl3): 172.9, 172.3, 155.5 (C=O), 84.2 (C≡CCH2), 80.1 (C(CH3)3), 68.6 (C≡CCH2), 65.3 (OCH2), 50.3, 48.1 (CH Ala), 28.4 (C(CH3)3), 28.1, 28.0, 24.9 (CH2), 18.4 (CH3 Ala), 18.3 (CH2, CH3 Ala). FT-IR (cm–1, ATR): 3299 (NH), 2116 (C≡C), 1711 (C=O ester), 1663 (Amide I), 1513 (amide II). MS-ESI m/z = 377 [M+Na]+. HRMS for $C_{18}H_{30}N_2O_5Na$: Calcd 377.2052 Found: 377.2050.

Table 1. Selected IR (ν in cm^{-1}) and ^1H NMR (measured in $CDCl_3$, δ in ppm) spectral data

	ν_{NH} (CH_2Cl_2)	$\nu_{amide\ I}$ (CH_2Cl_2)	ν_{NH} (solid)	$\nu_{amide\ I}$ (solid)	δ_{NH} ($CHCl_3$)
D,L-IAAPE (9)	3434	1710, 1692	3277	1665	
D,L-PIAAPE(10)	3264	1657	3271	1653	
D,L-IAAPETMS (11)	3427	1711, 1692	3318	1668	
D,L-PIAAPETMS (12)	3268, 3320	1657	3284	1655	8.5
L,L-IAAPE	3430	1710, 1694	3281	1665	
L,L-PIAAPE (13)	3261	1656	3280, 3262	1655	9.3
D,L-IAAHE	3431	1689	3299	1673	
D,L-PIAAHE (14)	3266	1656	3264	1655	8.9
L,L-IAAHE	3429	1689	3291	1672	
L,L-PIAAHE (15)	3288	-[a]	3356, 3284	1685, 1644	8.7

[a] No shift observed for the Amide I vibration

Supplementary material (ESI) for Journal of Materials Chemistry

Circular Dichroism

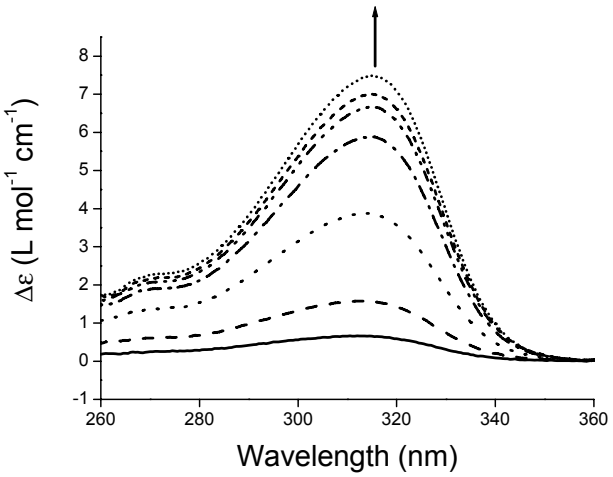

Figure 1 CD monitored polymerisation of **13** with 1/30 equiv. of Ni(II).

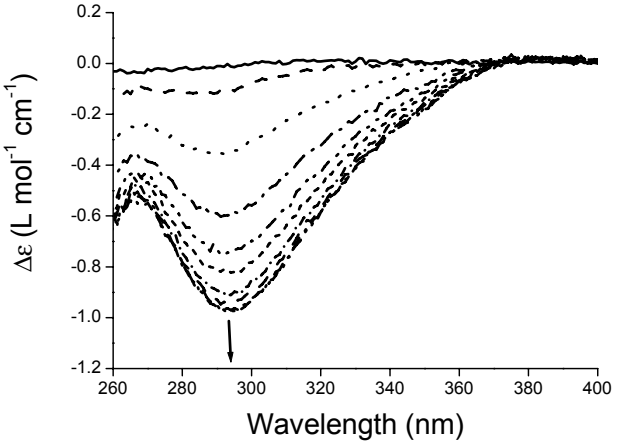

Figure 2 CD monitored polymerisation of **15** with 1/30 equiv. of Ni(II).

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X-ray data

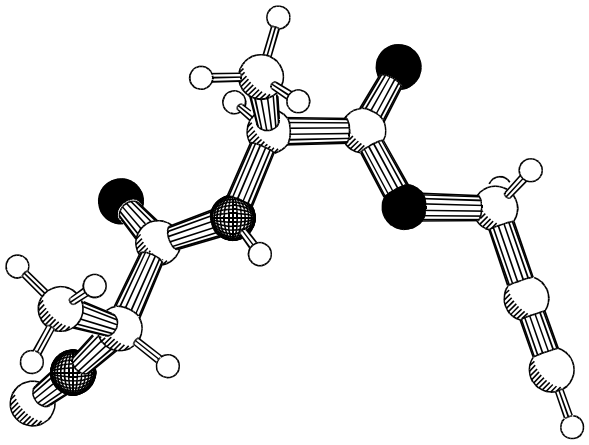

Figure 3 Single crystal X-ray structure of monomer **9**

Table 2 Crystal data and structure refinement for **9**.

Identification code	ERIK07
Crystal colour	translucent colourless
Crystal shape	rough fragment
Crystal size	0.23 x 0.18 x 0.03 mm
Empirical formula	C10 H12 N2 O3
Formula weight	208.22
Temperature	298(2) K
Radiation / Wavelength	MoKalpha (graphite mon.) / 0.71073 A

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Crystal system, space group	Triclinic, P1
Unit cell dimensions 23 reflections 2.110 < theta < 25.000)	a, alp= 4.7566(12) A, 72.97(6) deg. b, bet= 6.225(2) A, 85.49(8) deg. c, gam= 10.116(17) A, 80.83(3) deg.
Volume	282.6(5) A^3
Z, Calculated density	1, 1.224 Mg/m^3
Absorption coefficient	0.092 mm^-1
Diffractometer / scan	Nonius KappaCCD with area detector / phi and omega scan
F(000)	110
Theta range for data collection	2.11 to 25.00 deg.