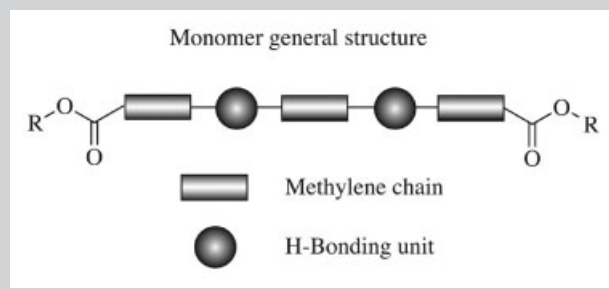


**Summary:** A series of poly(ether ester)s containing amide and carbamate groups as H-bonding units and 13–50 mol-% of poly(ethylene glycol) (PEG) segments were prepared by polycondensation in bulk using  $\text{Ti}(\text{OBU})_4$  as a catalyst. The copolymers were obtained starting from PEG/1,4-butanediol mixtures and a synthetic monomer carrying H-bonding groups. These polymers were designed for biomedical applications, where material biodegradability is required. The influence of the nature of the H-bonding units, the length of the polymethylene spacer between the H-bonding groups and the PEG content on the thermal and solubility properties of the copolymers was investigated. Amide-containing copolymers were more thermally stable than those containing carbamate groups. The PEG content also slightly affected the polymer thermal stability. The DSC traces of all samples presented multiple transitions, whose shape and peak tempe-

rature were strongly dependent on the PEG content. Polymer hydrophilicity, surface free energy and equilibrium swelling in phosphate buffer solution (PBS) at 37 °C were mainly influenced by the PEG content, whereas the nature of the H-bonding groups had little effect.



# Segmented Multifunctional Poly(ether ester) Polymers Containing H-Bonding Units. Preparation and Characterization

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## Introduction

In the last twenty years, polymer research and related industrial production have focused on very specific materials to be used in high performance applications. Among them, functional polymers for biomedical uses (biomaterials) started to be successfully introduced in clinical trials, in order to overcome some of the problems connected with available medical treatments. A requisite of biomaterials is that both their bulk and surface properties must be carefully designed and tuned to achieve the required properties. In particular, control of their degradation behavior, the biocompatibility of both polymers and degradation products and investigations into long-term toxicity are required. This can be combined with suitable release kinetics of incorporated pharmacologically active molecules. Accordingly, the development of new biomaterials for specific applications

uses the design of highly engineered macromolecular chains, whose properties can be easily tuned and optimized by modulating their chemical structure.<sup>[1]</sup>

In the framework of a long-standing research interest in the tailoring of polymers for biomedical-pharmaceutical applications,<sup>[2–10]</sup> attention has been directed on the synthesis and characterization of poly(ether-ester)s containing H-bonding units and poly(ethylene glycol) (PEG) segments. In principle, this class of materials should be endowed with an optimal combination of properties, i.e. the biodegradability of polyesters, the biocompatibility of polyethers and the excellent mechanical properties of phase separated, physically cross-linked materials, such as polyamides. In recent years, similar materials have been synthesized<sup>[11,12]</sup> and applied in the biomedical field, as both scaffolds for tissue engineering applications<sup>[13]</sup> and matrices for drug delivery applications.<sup>[14]</sup> In order to

evaluate and optimize the combination of the material properties, in the present investigation copolymers differing in the nature of the H-bonding unit and in the chemical composition were synthesized. Material structural features were correlated with bulk and surface properties, the type of H-bonding group, the length of the polymethylene spacer and PEG content.

## Experimental Part

### Materials

Symmetric diester-terminated H-bonding monomers were prepared as reported elsewhere.<sup>[15]</sup> 1,4-Butanediol (Aldrich) was heated at 80 °C on CaH<sub>2</sub> powder for 6 h under a dry argon atmosphere and then distilled (b.p. 100–104 °C/10 mbar). Poly(ethylene glycol) having 1 000 average molecular weight (PEG1000, Aldrich) was dried by azeotropic distillation using dry toluene and then stored under a dry argon atmosphere. Tetra-butyl orthotitanate (Merck) and Irganox 1330 (Ciba) were used as received. All solvents were dried over Na<sub>2</sub>SO<sub>4</sub> before use.

### Methods

All polymeric products were dried overnight under a vacuum (0.1 mbar) at 40 °C. Solubility tests were performed by using 5% (w/w) solutions. Equilibrium swelling ratios were evaluated on polymer films in PBS at 37 °C. Static contact angle measurements were performed on polymer cast films, using an OCA 15 Contact Angle Goniometer. Polymer films were cast on glass slides from 0.5% polymer solutions and carefully dried under vacuum. Measurements were performed 5 s after the drop reached the polymer surface by using Millipore<sup>®</sup> water and CH<sub>2</sub>I<sub>2</sub> as wetting agents. The contact angles were averaged over six measurements. Viscosity measurements were carried out on polymer solutions in 1:1 (v/v) CHCl<sub>3</sub>/MeOH at 25 °C by using an Ubbelohde OC viscometer. FT-IR spectra were recorded under a dry nitrogen atmosphere on KBr pellets using a BIORAD FTS-60 spectrophotometer. <sup>1</sup>H NMR and <sup>13</sup>C NMR spectra were recorded on 5–10% sample solutions in perdeuterated solvents with a Varian 300 spectrometer. Peak multiplicity is denoted as: s (singlet), d (doublet), dd (double doublet), t (triplet) q (quartet), m (multiplet) or b (broad signal). Differential scanning calorimetry (DSC) measurements were performed between –80 and 200 °C at a heating rate of 10 °C · min<sup>-1</sup> on 5–10 mg samples under a dry nitrogen atmosphere using a Mettler TC11 calorimeter. Glass transition temperatures were measured from the inflection points in the thermograms of the second heating cycle. Thermal gravimetric analyses (TGA) were carried out between 30 and 700 °C at a heating rate of 10 °C · min<sup>-1</sup> on 10–12 mg samples under a nitrogen atmosphere using a TGA 7 Perkin Elmer instrument. The initial decomposition temperature (*T*<sub>d</sub>) corresponding to 5% weight loss, *T*<sub>d1</sub>–*T*<sub>d3</sub> (inflection point temperatures), Δ*w*<sub>1</sub>–Δ*w*<sub>3</sub> (percent weight losses of the different degradation steps) and *MR*<sub>700</sub> (mass residue at 700 °C) were recorded.

### Monomers

Monomer synthesis was performed as reported elsewhere.<sup>[15]</sup> Briefly, the amide containing monomers dimethyl 7,12-diaza-

6,13-dioxo-1,18-octadecanedioate (M4A4) and dimethyl 9,16-diaza-8,17-dioxo-1,24-tetracosanedioate (M6A6) were prepared starting from 1:10 1,4-diaminobutane/dimethyl adipate and a 1,6-diaminohexane/dimethyl suberate mixture, respectively, using Ti(OBu)<sub>4</sub> as catalyst. The mixture was heated at 150 °C for 8 h and the crude reaction products were submitted to continuous extraction with boiling chloroform. Removal of the solvent under vacuum afforded the two monomers in 62 and 88% yield, respectively. Diethyl 9,16-diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate (E5C6) was prepared with a 98% yield by heating a 2:1 mixture of ethyl 6-hydroxyhexanoate and hexamethylenediisocyanate in dry toluene at 70 °C for 17 h.

### Polymers

Polymerization experiments of 1,4-butanediol/PEG1000 mixtures with dimethyl 7,12-diaza-6,13-dioxo-1,18-octadecanedioate (Sample pA4-30), dimethyl 9,16-diaza-8,17-dioxo-1,24-tetracosanedioate (Sample pA6-30) and diethyl 9,16-diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate (Sample pC6-30) were performed as reported elsewhere.<sup>[15]</sup> The other polymer samples were prepared according to a common procedure. The preparation of pA4-40 is described in detail as a typical example and information on the other experiments is summarized thereafter.

Polymerization of Dimethyl 7,12-Diaza-6,13-dioxo-1,18-octadecanedioate with a 1,4-Butanediol/PEG1000 Mixture (Run pA4-40)

PEG1000 (2.5 g, 2.5 mmol), 1,4-butanediol (1.5 g, 16 mmol), M4A4 (5.0 g, 13 mmol), 179 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (26.4 μmol) and Irganox 1330 (90 mg) were placed under a dry argon atmosphere in a glass vessel equipped with a magnetic stirrer and connected to a condenser trap. The mixture was stirred for 1 h at 100 °C, for 2 h at 165 °C/15 mbar and for 32 h at 165 °C/0.1 mbar. After cooling to room temperature, the crude product was dissolved in 1:1 (v/v) chloroform/methanol, precipitated in diethyl ether and then dried under a vacuum to constant weight to give 7.1 g (84%) of polymeric product.

FT-IR (cast film): 3 305 (ν NH), 1 721 (ν C=O ester), 1 636 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (300 MHz, DMSO-*d*<sub>6</sub>): δ = 7.8 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 4H, COOCH<sub>2</sub>CH<sub>2</sub>O), 3.5 (t, 80H, CH<sub>2</sub>O) 3.0 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.0 (t, 8H; CH<sub>2</sub>CONH), 1.6 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.5 (m, 16H, CH<sub>2</sub>), 1.3 (m, 8H; CH<sub>2</sub>CH<sub>2</sub>NH).

<sup>13</sup>C NMR (300 MHz, DMSO-*d*<sub>6</sub>): δ = 172.8 (CONH), 171.6 (COO), 69.5 (OCH<sub>2</sub>CH<sub>2</sub>O), 68.3 (OCH<sub>2</sub>CH<sub>2</sub>OCO), 63.3 (CH<sub>2</sub>OCO), 63.0 (CH<sub>2</sub>OCO), 38.1 (CH<sub>2</sub>NHCO), 34.9 (CH<sub>2</sub>-CONH), 33.2 (CH<sub>2</sub>COO), 26.6 (CH<sub>2</sub>CH<sub>2</sub>NH), 24.8 (CH<sub>2</sub>CH<sub>2</sub>-OCO), 24.7 (CH<sub>2</sub>), 24.0 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Dimethyl 7,12-Diaza-6,13-dioxo-1,18-octadecanedioate with a 1,4-Butanediol/PEG1000 Mixture (Run pA4-50)

A mixture of M4A4 (5.0 g, 13 mmol), PEG1000 (3.4 g, 3.0 mmol), 1,4-butanediol (1.3 g, 15 mmol), 194 μl of 5%

Ti(OBu)<sub>4</sub> toluene solution (28.5 μmol) and Irganox 1330 (97 mg) was used. The crude product was dissolved in 1:1 (v/v) chloroform/methanol and then precipitated in diethyl ether to give 6.0 g (65%) of polymeric product.

FT-IR (cast film): 3304 (ν NH), 1721 (ν C=O ester), 1636 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>): δ = 7.8 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 4H, COOCH<sub>2</sub>CH<sub>2</sub>O), 3.5 (t, 80H, CH<sub>2</sub>O) 3.0 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.0 (t, 8H; CH<sub>2</sub>CONH), 1.6 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.5 (m, 16H, CH<sub>2</sub>), 1.3 (m, 8H; CH<sub>2</sub>CH<sub>2</sub>NH).

<sup>13</sup>C NMR (DMSO-*d*<sub>6</sub>): δ = 172.8 (CONH), 171.6 (COO), 69.5 (OCH<sub>2</sub>CH<sub>2</sub>O), 68.3 (OCH<sub>2</sub>CH<sub>2</sub>OCO), 63.3 (CH<sub>2</sub>OCO), 63.0 (CH<sub>2</sub>OCO), 38.1 (CH<sub>2</sub>NHCO), 34.9 (CH<sub>2</sub>CONH), 33.2 (CH<sub>2</sub>COO), 26.6 (CH<sub>2</sub>CH<sub>2</sub>NH), 24.8 (CH<sub>2</sub>CH<sub>2</sub>OCO), 24.7 (CH<sub>2</sub>), 24.0 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Dimethyl 7,12-diaza-6,13-dioxo-1,18-octadecanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pA4-70)

A mixture of M4A4 (5.0 g, 13 mmol), PEG1000 (5.9 g, 6.0 mmol), 1,4-butanediol (1.0 g, 11 mmol), 239 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (35.0 μmol) and Irganox 1330 (119 mg) was used. The crude product was dissolved in 1:1 (v/v) chloroform/methanol and then precipitated in diethyl ether to give 9.1 g (79%) of polymeric product.

FT-IR (cast film): 3305 (ν NH), 1722 (ν C=O ester), 1636 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>): δ = 7.8 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 4H, COOCH<sub>2</sub>CH<sub>2</sub>O), 3.5 (t, 80H, CH<sub>2</sub>O) 3.0 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.0 (t, 8H; CH<sub>2</sub>CONH), 1.6 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.5 (m, 16H, CH<sub>2</sub>), 1.3 (m, 8H; CH<sub>2</sub>CH<sub>2</sub>NH).

<sup>13</sup>C NMR (DMSO-*d*<sub>6</sub>): δ = 172.8 (CONH), 171.6 (COO), 69.5 (OCH<sub>2</sub>CH<sub>2</sub>O), 68.3 (OCH<sub>2</sub>CH<sub>2</sub>OCO), 63.3 (CH<sub>2</sub>OCO), 63.0 (CH<sub>2</sub>OCO), 38.1 (CH<sub>2</sub>NHCO), 34.9 (CH<sub>2</sub>CONH), 33.2 (CH<sub>2</sub>COO), 26.6 (CH<sub>2</sub>CH<sub>2</sub>NH), 24.8 (CH<sub>2</sub>CH<sub>2</sub>OCO), 24.7 (CH<sub>2</sub>), 24.0 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Dimethyl 9,16-Diaza-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pA6-40)

A mixture of M6A6 (5.0 g, 11 mmol), PEG1000 (2.2 g, 2.0 mmol), 1,4-butanediol (1.2 g, 13 mmol), 169 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (23.5 μmol) and Irganox 1330 (80 mg) was used. The crude product was dissolved in 1:1 (v/v) chloroform/methanol and then precipitated in ethanol and diethyl ether to give 7.1 g (89%) of polymeric product.

FT-IR (cast film): 3304 (ν NH), 1732 (ν C=O ester), 1634 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (CDCl<sub>3</sub>): δ = 6.3–6.0 (b, 4H, NH), 4.2 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.1 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 80H, CH<sub>2</sub>O) 3.2 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.2 (t, 8H; CH<sub>2</sub>CONH), 1.7 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.6 (b, 6H, CH<sub>2</sub>CH<sub>2</sub>NH and CH<sub>2</sub>CH<sub>2</sub>O), 1.5 (m, 16H, CH<sub>2</sub>CH<sub>2</sub>CONH), 1.3 (m, 8H; CH<sub>2</sub>).

<sup>13</sup>C NMR (CDCl<sub>3</sub>): δ = 173.7 (CONH), 173.1 (COO), 70.5 (COOCH<sub>2</sub>CH<sub>2</sub>O), 69.1 (OCH<sub>2</sub>CH<sub>2</sub>O), 63.7 (CH<sub>2</sub>OCO),

63.3 (CH<sub>2</sub>OCO), 39.0 (CH<sub>2</sub>NHCO) 36.6 (CH<sub>2</sub>CONH), 34.1 (CH<sub>2</sub>COO), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NH), 28.9 (CH<sub>2</sub>), 26.0 (CH<sub>2</sub>), 25.6 (CH<sub>2</sub>), 25.3 (CH<sub>2</sub>CH<sub>2</sub>CONH), 24.7 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Dimethyl 9,16-Diaza-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pA6-50)

A mixture of M6A6 (5.0 g, 11 mmol), PEG1000 (3.0 g, 3 mmol), 1,4-butanediol (1.1 g, 12 mmol), 181 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (25.6 μmol) and Irganox 1330 (87 mg) was used. The crude product was dissolved in chloroform/methanol (1:1 v/v) and precipitated in diethyl ether to give 7.1 g (81%) of polymeric product.

FT-IR (cast film): 3304 (ν NH), 1731 (ν C=O ester), 1634 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (CDCl<sub>3</sub>): δ = 6.3–6.0 (b, 4H, NH), 4.2 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.1 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 80H, CH<sub>2</sub>O) 3.2 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.2 (t, 8H; CH<sub>2</sub>CONH), 1.7 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.6 (b, 6H, CH<sub>2</sub>CH<sub>2</sub>NH and CH<sub>2</sub>CH<sub>2</sub>O), 1.5 (m, 16H, CH<sub>2</sub>CH<sub>2</sub>CONH), 1.3 (m, 8H; CH<sub>2</sub>).

<sup>13</sup>C NMR (CDCl<sub>3</sub>): δ = 173.7 (CONH), 173.1 (COO), 70.5 (COOCH<sub>2</sub>CH<sub>2</sub>O), 69.1 (OCH<sub>2</sub>CH<sub>2</sub>O), 63.7 (CH<sub>2</sub>OCO), 63.3 (CH<sub>2</sub>OCO), 39.0 (CH<sub>2</sub>NHCO) 36.6 (CH<sub>2</sub>CONH), 34.1 (CH<sub>2</sub>COO), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NH), 28.9, 26.0, and 25.6 (CH<sub>2</sub>), 25.3 (CH<sub>2</sub>CH<sub>2</sub>CONH), 24.7 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Dimethyl 9,16-Diaza-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pA6-70)

A mixture of M6A6 (5.0 g, 11 mmol), PEG1000 (5.1 g, 5.0 mmol), 1,4-butanediol (0.8 g, 9 mmol), 169 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (23.5 μmol) and Irganox 1330 (80 mg) was used. The crude product was dissolved in CHCl<sub>3</sub> and precipitated in diethyl ether to give 9.1 g (86%) of polymeric product.

FT-IR (cast film): 3304 (ν NH), 1731 (ν C=O ester), 1634 cm<sup>-1</sup> (ν C=O amide).

<sup>1</sup>H NMR (CDCl<sub>3</sub>): δ = 6.3–6.0 (b, 4H, NH), 4.2 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.1 (t, 4H, CH<sub>2</sub>OCO), 3.6 (t, 80H, CH<sub>2</sub>O) 3.2 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 2.2 (t, 8H; CH<sub>2</sub>CONH), 1.7 (m, 4H; CH<sub>2</sub>CH<sub>2</sub>OCO), 1.6 (b, 6H, CH<sub>2</sub>CH<sub>2</sub>NH and CH<sub>2</sub>CH<sub>2</sub>O), 1.5 (m, 16H, CH<sub>2</sub>CH<sub>2</sub>CONH), 1.3 (m, 8H; CH<sub>2</sub>).

<sup>13</sup>C NMR (CDCl<sub>3</sub>): δ = 173.7 (CONH), 173.1 (COO), 70.5 (COOCH<sub>2</sub>CH<sub>2</sub>O), 69.1 (OCH<sub>2</sub>CH<sub>2</sub>O), 63.7 (CH<sub>2</sub>OCO), 63.3 (CH<sub>2</sub>OCO), 39.0 (CH<sub>2</sub>NHCO) 36.6 (CH<sub>2</sub>CONH), 34.1 (CH<sub>2</sub>COO), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NH), 28.9, 26.0, and 25.6 (CH<sub>2</sub>), 25.3 (CH<sub>2</sub>CH<sub>2</sub>CONH), 24.7 (CH<sub>2</sub>CH<sub>2</sub>COO).

Polymerization of Diethyl 9,16-Diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pC6-40)

A mixture of E5C6 (5.0 g, 10 mmol), PEG1000 (2.1 g, 2.0 mmol), 1,4-butanediol (1.1 g, 12 mmol), 164 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (24.1 μmol) and Irganox 1330 (82 mg) was used. The crude product was dissolved in chloroform



and precipitated in 1:1 (v/v) ethanol/diethyl ether to give 2.8 g (35%) of polymeric product.

FT-IR (cast film): 3327 (ν NH), 1731 (ν C=O ester, sh), 1689 cm<sup>-1</sup> (ν C=O carbamate).

<sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>): δ = 7.2–6.7 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0–3.8 (m, 10H, CH<sub>2</sub>OCO and CH<sub>2</sub>OCONH), 3.5 (t, 80H, CH<sub>2</sub>O), 2.9 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H, CH<sub>2</sub>COO), 1.6–1.4 (m, 12H; CH<sub>2</sub>), 1.4–1.2 (b, 12H, CH<sub>2</sub>).

<sup>13</sup>C NMR (DMSO-*d*<sub>6</sub>): δ = 172.8 (COO), 156.2 (OCONH), 69.8 (CH<sub>2</sub>OCO), 68.9 (COOCH<sub>2</sub>CH<sub>2</sub>O), 68.2 (COOCH<sub>2</sub>CH<sub>2</sub>O), 63.5 (CH<sub>2</sub>OCO), 63.1 (CH<sub>2</sub>OCONH), 33.4 (OCONHCH<sub>2</sub>), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NHCO), 28.4 (CH<sub>2</sub>CH<sub>2</sub>COO), 25.9, 25.4, 24.9, 24.1 (CH<sub>2</sub>).

Polymerization of Diethyl 9,16-Diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pC6-50)

A mixture of E5C6 (5.0 g, 10 mmol), PEG1000 (2.9 g, 3.0 mmol), 1,4-butanediol (1.0 g, 11 mmol), 177 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (26.1 μmol) and Irganox 1330 (89 mg) was used. The crude product was dissolved in chloroform and then precipitated in diethyl ether to give 5.4 g (63%) of polymeric product.

FT-IR (cast film): 3327 (ν NH), 1731 (ν C=O ester, sh), 1686 cm<sup>-1</sup> (ν C=O carbamate).

<sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>): δ = 7.2–6.7 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0–3.8 (m, 10H, CH<sub>2</sub>OCO and CH<sub>2</sub>OCONH), 3.5 (t, 80H, CH<sub>2</sub>O), 2.9 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 1.6–1.4 (m, 12H; CH<sub>2</sub>), 1.4–1.2 (b, 12H, CH<sub>2</sub>).

<sup>13</sup>C NMR (DMSO-*d*<sub>6</sub>): δ = 172.8 (COO), 156.2 (OCONH), 69.8 (CH<sub>2</sub>OCO), 68.9 (COOCH<sub>2</sub>CH<sub>2</sub>O), 68.2 (COOCH<sub>2</sub>CH<sub>2</sub>O), 63.5 (CH<sub>2</sub>OCO), 63.1 (CH<sub>2</sub>OCONH), 33.4 (OCONHCH<sub>2</sub>), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NHCO), 28.4 (CH<sub>2</sub>CH<sub>2</sub>COO), 25.9, 25.4, 24.9, 24.1 (CH<sub>2</sub>).

Polymerization of Diethyl 9,16-Diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate with a 1,4-Butandiol/PEG1000 Mixture (Run pC6-70)

A mixture of E5C6 (5.0 g, 10 mmol), PEG1000 (4.9 g, 5.0 mmol), 1,4-butanediol (0.7 g, 8 mmol), 211 μl of 5% Ti(OBu)<sub>4</sub> toluene solution (31.1 μmol) and Irganox 1330 (106 mg) was used. The crude product was dissolved in chloroform and then precipitated in diethyl ether to give 8.2 g (79%) of polymeric product.

FT-IR (cast film): 3327 (ν NH), 1731 (ν C=O ester, sh), 1687 cm<sup>-1</sup> (ν C=O carbamate).

<sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>): δ = 7.2–6.7 (m, 4H, NH), 4.1 (t, 4H, OCH<sub>2</sub>CH<sub>2</sub>OCO), 4.0–3.8 (m, 10H, CH<sub>2</sub>OCO and CH<sub>2</sub>OCONH), 3.5 (t, 80H, CH<sub>2</sub>O), 2.9 (m, 8H, CH<sub>2</sub>NHCO), 2.3 (t, 8H; CH<sub>2</sub>COO), 1.6–1.4 (m, 12H; CH<sub>2</sub>), 1.4–1.2 (b, 12H, CH<sub>2</sub>).

<sup>13</sup>C NMR (DMSO-*d*<sub>6</sub>): δ = 172.8 (COO), 156.2 (OCONH), 69.8 (CH<sub>2</sub>OCO), 68.9 (COOCH<sub>2</sub>CH<sub>2</sub>O), 68.2 (COOCH<sub>2</sub>CH<sub>2</sub>O), 63.5 (CH<sub>2</sub>OCO), 63.1 (CH<sub>2</sub>OCONH), 33.4 (OCONHCH<sub>2</sub>), 29.4 (CH<sub>2</sub>CH<sub>2</sub>NHCO), 28.4 (CH<sub>2</sub>CH<sub>2</sub>COO), 25.9, 25.4, 24.9, 24.1 (CH<sub>2</sub>).

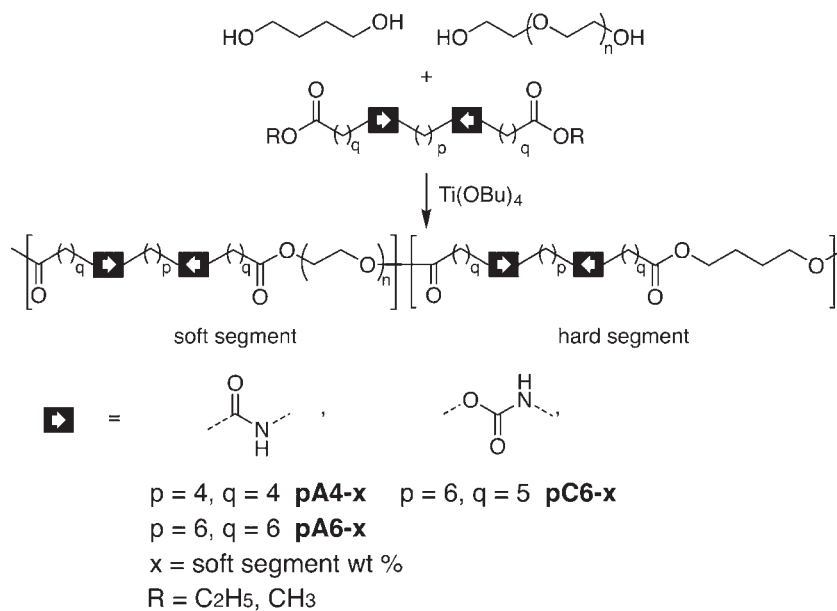
## Results and Discussion

### Polymerization

Diester-terminated symmetrical monomers containing either amide or carbamate moieties, i.e. dimethyl 7,12-diaza-6,13-dioxo-1,18-octadecanedioate (M4A4), dimethyl 9,16-diaza-8,17-dioxo-1,24-tetracosanedioate (M6A6) and diethyl 9,16-diaza-7,18-dioxa-8,17-dioxo-1,24-tetracosanedioate (E5C6), were synthesized in good yield and with high purities as reported elsewhere.<sup>[15]</sup> These functional monomers were prepared to be incorporated as H-bonding segments in poly(ether ester) materials. Their different structures allowed for evaluating the effect of different H-bonding segments (amide and carbamate) and of the alkylene chain length (four and six methylene units) on the final polymer properties. Three series of polymers were prepared by bulk polycondensation of PEG1000/1,4-butanediol mixtures with either one of the three monomers (M4A4, M6A6, and E5C6) to give pA4-x, pA6-x, and pC6-x polymer series (Scheme 1). The macromolecular chains of the resulting segmented polymers (Figure 1) are constituted of sequences of “soft” and “hard” segments, whose constitutional units are identified by their conformational degree of freedom. For each polymer series, the variable x refers to the percentage of polymer soft block. The final hard/soft balance of the polymers was easily tailored by changing the composition of the feed diol mixture, aiming for 10:4:6, 10:5:5, and 10:7:3 diester/PEG1000/1,4-butanediol final molar ratios, in order to study the effect of the increasing PEG content on polymer properties.

Polymerization conditions were optimized in order to avoid monomer thermal degradation, which leads to low molecular weight products or uncontrolled crosslinking of the growing chains. Taking into account the thermal stability of the monomers containing amide (M4A4 and M6A6) and carbamate groups (E5C6), the final polymerization temperature was set at 165 °C. High molecular weight polymers were obtained at this temperature and no competitive thermal degradation of the monomers occurred.<sup>[15]</sup> A few samples of the more thermally stable amide-type copolymers were prepared at 220 °C, for comparison with literature data.<sup>[15]</sup> During polymerization, the temperature was progressively increased from room temperature up to the final set value, whereas the pressure was progressively decreased to 0.1 mbar in order to facilitate the removal of volatile polycondensation products. Tetrabutyl titanate [Ti(OBu)<sub>4</sub>] was selected as the catalyst in all experiments, since its activity as condensation promoter of esters with alcohols is well established.<sup>[16]</sup> Moreover, to prevent PEG1000 from thermal oxidation, 1% by weight of Irganox 1330 was used in all cases as an antioxidant. The results of the polycondensation reactions are presented in Table 1.

The polymerization mechanism is supposed to entail two steps,<sup>[14]</sup> independent of the diol mixture composition. The first one involves the transesterification of the



Scheme 1. Polycondensation of monomers containing H-bonding units with different composition PEG1000 diol/1,4-butanediol mixtures.

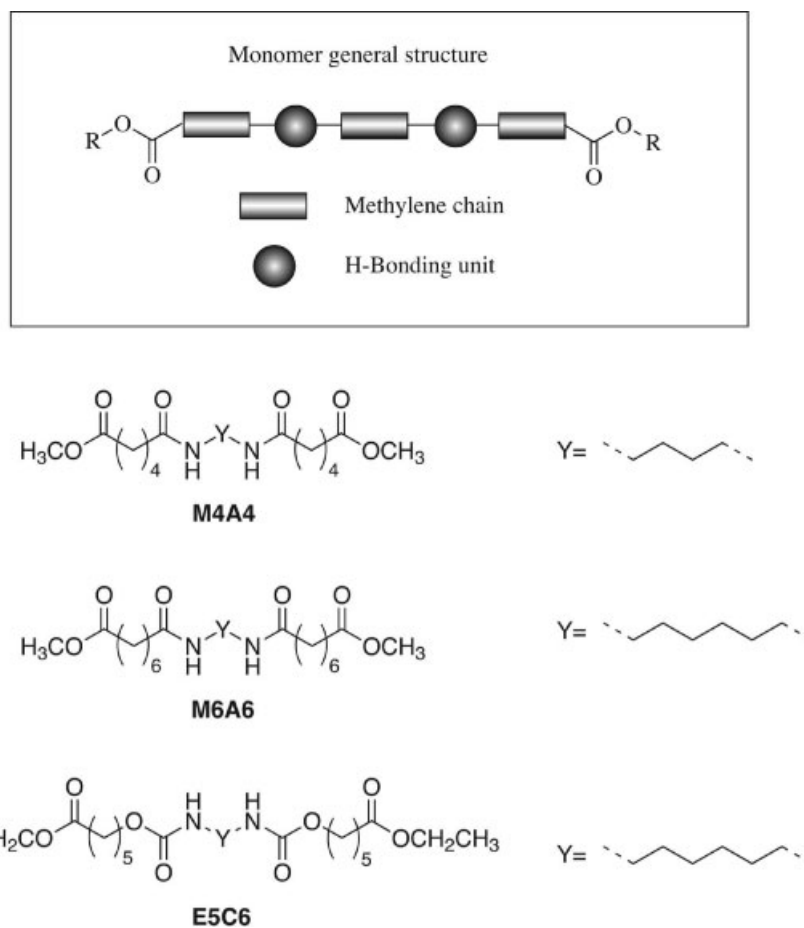


Figure 1. Structure of the bisamide and biscarbamate monomers.

Table 1. Polycondensation of H-bonding monomers with 1,4-butanediol and PEG1000 mixtures.

Run	Polymerization conditions					PEG1000		Yield %	[ $\eta$ ] dL · g <sup>-1</sup>
	H-bonding monomer			Final T	Duration	Feed <sup>a)</sup>	Polymer <sup>a,b)</sup>		
	Type	H-bonding group	mol-%	°C	h	mol-%	mol-%		
pA4-30 <sup>c)</sup>	M4A4	Amide	42	220	24	10	13	68	0.86
pA4-40	M4A4	Amide	42	165	35	11	22	84	0.36
pA4-50	M4A4	Amide	42	165	35	17	21	65	0.32
pA4-70	M4A4	Amide	43	165	35	35	39	79	0.33
pA6-30 <sup>c)</sup>	M6A6	Amide	42	220	24	10	15	30	1.47
pA6-40	M6A6	Amide	42	165	35	13	19	89	0.40
pA6-50	M6A6	Amide	42	165	35	20	25	81	0.32
pA6-70	M6A6	Amide	44	165	35	36	50	53	0.42
pC6-30 <sup>c)</sup>	E5C6	Carbamate	42	165	35	10	13	66	0.55
pC6-40	E5C6	Carbamate	40	165	35	14	19	35	0.49
pC6-50	E5C6	Carbamate	42	165	35	21	24	63	0.56
pC6-70	E5C6	Carbamate	43	165	35	38	45	79	0.61

<sup>a)</sup> Calculated as  $100 \cdot [\text{PEG}] / ([\text{PEG}] + [1,4\text{-butanediol}])$ .

<sup>b)</sup> Determined by <sup>1</sup>H NMR analysis.

<sup>c)</sup> From ref.<sup>[15]</sup>

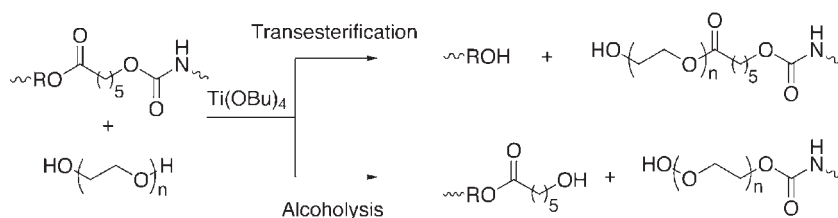
diester monomer with PEG1000 and 1,4-butanediol. This reaction proceeds while the temperature is progressively increased from room temperature up to 165 °C and the pressure is slowly decreased to 15 mbar. The reaction equilibrium is shifted towards the products by distilling off the formed methanol. The second step, performed at the final temperature and pressure, promotes the coupling of the formed oligomers to give high molecular weight condensation products upon distillation of 1,4-butanediol. A molar excess of diol monomers was used in all polymerization experiments, to assure quantitative conversion of the H-bonding promoting units (M4A4, M6A6, E5C6).

### Polymer Characterization

The PEG content of the copolymers was determined by <sup>1</sup>H NMR analysis. The polymer composition, as evaluated from the integral ratio of the signals at 4.1–4.0 ppm (methylene groups in the  $\alpha$ -position of the ester oxygen) and at 3.5 ppm (remaining PEG methylene groups) was slightly larger than the molar ratio of the corresponding feed. This

result indicates that a small amount of 1,4-butanediol distilled off from the polymerization mixture under the applied experimental conditions. It is worth noting that the PEG content of the pC6-x samples, as evaluated from the integrals of the peaks at 4.0 and 4.1 ppm, resulted in about one half of that in the feed. On the other hand, the polymer composition was found to be close to the polymerization feed if the signal at 3.5 ppm was considered. Comparison of <sup>1</sup>H and <sup>13</sup>C NMR data indicated that this deviation resulted from the occurrence of carbamate alcoholysis (Scheme 2). This reaction competes with the expected transesterification process giving rise to asymmetrical carbamate segments.<sup>[15]</sup>

No signal attributable to polymer end groups could be detected in the <sup>13</sup>C NMR spectra of the polymers, indicating the formation of high molecular weight products. Although the available information does not allow us to rule out the occurrence of cyclization reactions, it seems reasonable to assume that no significant amount of macrocyclic compounds was formed, particularly taking into account that copolymerization experiments were carried out in bulk.<sup>[17]</sup>



Scheme 2. Carbamate transesterification and alcoholysis during the synthesis of poly(ether ester carbamate)s.

The polymer viscosity was measured at 25 °C in 1:1 chloroform/methanol solution. Since the Mark-Houwink constants of the investigated polymers are not known, the intrinsic viscosity  $[\eta]$  was used as an indication of polymer molar mass. The values reported in Table 1 are in agreement with medium-to-high molecular weights. In all cases, a linear relationship between polymer concentration and reduced viscosity was observed, indicating that no significant crosslinking reactions occurred during polymerization. Solubility properties confirmed that no crosslinking occurred.

The PEG content appreciably affected the polymer solubility. In general, an increased solubility in polar aprotic solvents was observed at higher PEG contents, because of both the increased hydrophilicity and the larger mobility of polymer chains. The pC6-70 sample, having the highest PEG content in the poly(ether ester carbamate) series was soluble in warm water.

### Thermal Properties

The thermal properties of the prepared materials were determined by TGA and DSC analyses. The polymer thermal stability was evaluated by TGA in the 30–700 °C range at a heating rate of 10 °C · min<sup>-1</sup>. The results presented in Table 2 indicate that all polymer samples are stable up to temperatures higher than 270 °C. Moreover, the decomposition temperatures of polymers containing amide moieties are about 100 °C higher than that of materials containing carbamate units. Apparently, the PEG content did not affect the thermal stability of amide containing materials in terms of both initial degradation temperature ( $T_d$ ) and degradation pattern. Likewise, a comparison of the pA4-x and pA6-x samples of similar composition did not show any significant influence of the length of the

polymethylene spacer on the polymer thermal stability. Indeed, the decomposition of all poly(ether ester amide)s occurred in a single step centered at about 430 °C.

Although the initial decomposition temperatures of the poly(ether ester carbamate) series were hardly affected by the PEG content, some influence on the shape of the degradation curves was detected. Comparison of the PC6-x chemical compositions indicates that the decomposition steps at about 340 and 410 °C are very likely due to the degradation of carbamate groups and PEG segments, respectively. The small weight loss observed at about 465 °C can be tentatively attributed to the decomposition of tars formed by carbamate degradation.

DSC analyses were performed at a heating rate of 10 °C · min<sup>-1</sup> and the thermal behavior of the polymers was compared to that of the corresponding monomers containing H-bonding groups and to PEG1000 (Table 3). All copolymers exhibited one glass transition, attributable to the soft segment, and at least one endothermic peak corresponding to the melting of crystalline domains. The  $T_g$ s of the different samples decreased from approximately -37 °C to the value of PEG1000 (-56 °C) on increasing the PEG content. The length of the polyalkylene spacer also slightly affected the  $T_g$ . The pA6-x materials displayed lower glass transition temperatures than pA4-x polymers, most likely due to the larger flexibility of the longer polymethylene spacer. No significant influence of the nature of the H-bonding unit (amide or carbamate) was detected, in agreement with previous reports.<sup>[15]</sup>

In most cases, the DSC traces reflected the thermal behavior of the individual building blocks, i.e. PEG1000 and the H-bonding monomers (Figure 2 and 3). The low temperature endothermic transition ( $T_{m1}$ ) that appears at high PEG content must be attributed to the crystallization of PEG domains. High temperature endothermic transitions ( $T_{m2}$ ,

Table 2. TGA analysis of poly(ether ester)s containing H-bonding units with different PEG contents.

Run	$T_d^{a)}$	$T_{d1}$	$\Delta w_1$	$T_{d2}$	$\Delta w_2$	$T_{d3}$	$\Delta w_3$	$MR_{700}$
	°C	°C	%	°C	%	°C	%	%
pA4-30 <sup>b)</sup>	360	419	97	–	–	–	–	3
pA4-40	357	432	97	–	–	–	–	3
pA4-50	373	431	97	–	–	–	–	3
pA4-70	364	429	97	–	–	–	–	3
pA6-30 <sup>b)</sup>	398	437	97	–	–	–	–	3
pA6-40	381	435	96	–	–	–	–	4
pA6-50	373	440	96	–	–	–	–	4
pA6-70	369	442	95	–	–	–	–	5
pC6-30 <sup>b)</sup>	290	336	57	407	24	469	17	2
pC6-40	277	343	64	413	32	466	3	1
pC6-50	284	351	57	419	38	463	4	1
pC6-70	278	340	47	416	52	–	–	1

<sup>a)</sup> Corresponding to 5% weight loss.

<sup>b)</sup> From ref.<sup>[15]</sup>

Table 3. DSC analysis of poly(ether ester)s containing H-bonding units with different PEG content, the corresponding monomers containing H-bonding units, and PEG1000. Data is from second heating scan with a heating rate of  $10\text{ }^{\circ}\text{C}\cdot\text{min}^{-1}$  (nd = not determined).

Sample	PEG <sup>a)</sup>	$T_g$	$\Delta C_p$	$T_{m1}$	$\Delta H_{m1}$	$T_{m2}$	$\Delta H_{m2}$	$T_{m3}$	$\Delta H_{m3}$	$T_{m4}$	$\Delta H_{m4}$
	mol-%	$^{\circ}\text{C}$	$\text{J}\cdot\text{K}\cdot\text{g}^{-1}$	$^{\circ}\text{C}$	$\text{J}\cdot\text{g}^{-1}$	$^{\circ}\text{C}$	$\text{J}\cdot\text{g}^{-1}$	$^{\circ}\text{C}$	$\text{J}\cdot\text{g}^{-1}$	$^{\circ}\text{C}$	$\text{J}\cdot\text{g}^{-1}$
PEG1000	100	-56	nd	34	137	–	–	–	–	–	–
M4A4 <sup>b)</sup>	0	–	–	–	–	103	29	143	110	–	–
PA4-30 <sup>b)</sup>	12	-37	0.3	–	–	–	–	151	42	–	–
PA4-40	22	-51	0.3	–	–	–	–	146	22	–	–
PA4-50	21	-51	0.3	–	–	–	–	148	24	–	–
PA4-70	39	-51	0.4	29	27	–	–	134	26	–	–
M6A6 <sup>b)</sup>	0	–	–	–	–	–	–	133	85	151	13
PA6-30 <sup>b)</sup>	15	-45	0.4	–	–	103	16	130	6	–	–
PA6-40	19	-52	0.1	–	–	–	–	130	35	–	–
PA6-50	25	-56	0.3	–	–	–	–	125	29	–	–
PA6-70	50	-54	0.1	0	13	83	23	118	25	–	–
E5C5 <sup>b)</sup>	0	–	–	–	–	76	115	–	–	–	–
PC6-30 <sup>b)</sup>	12	-47	0.3	–	–	–	–	114	26	–	–
PC6-40	19	-52	0.5	–	–	–	–	104	16	–	–
PC6-50	24	-53	0.4	–	–	–	–	102	28	–	–
PC6-70	45	-53	0.5	20	31	76	9	–	–	–	–

<sup>a)</sup> Evaluated by  $^1\text{H}$  NMR as  $100 \cdot [\text{PEG}] / ([\text{PEG}] + [1,4\text{-butanediol}])$ .

<sup>b)</sup> From ref.<sup>[15]</sup>

$T_{m3}$  and  $T_{m4}$ ) are strictly related to the endothermic transitions observed in the DSC of the corresponding H-bonding monomers. Therefore, this transition was attributed to the melting of the hard blocks, whose crystallinity is mainly determined by the intermolecular H-bonded domains. The transitions  $T_{m2}$ ,  $T_{m3}$  and  $T_{m4}$  are relatively broad (about  $20\text{ }^{\circ}\text{C}$  wide), probably due to the random polycondensation process, which may lead to macromolecular chains with different compositions. It is also possible that the increasing presence of flexible PEG segments interferes with the hard segment crystallization giving rise to less ordered crystal structures that melt at lower temperatures.

### Surface Free Energy

It is well known that surface characteristics, such as hydrophilicity and phase separation, play a major role in the biological response to materials. The total free energy  $\gamma_s^T$  at a solid surface is the sum of the contributions of different intermolecular forces.<sup>[18]</sup> In particular, hydrogen bonding ( $\gamma_s^H$ ) and dispersion forces ( $\gamma_s^D$ ) contribute most to the surface energy. These two contributions can be effectively evaluated by measuring the contact angle  $\theta$  of the surfaces.<sup>[19]</sup> Accordingly, the static contact angle of water and  $\text{CH}_2\text{I}_2$  on the surface of the investigated polymers were determined

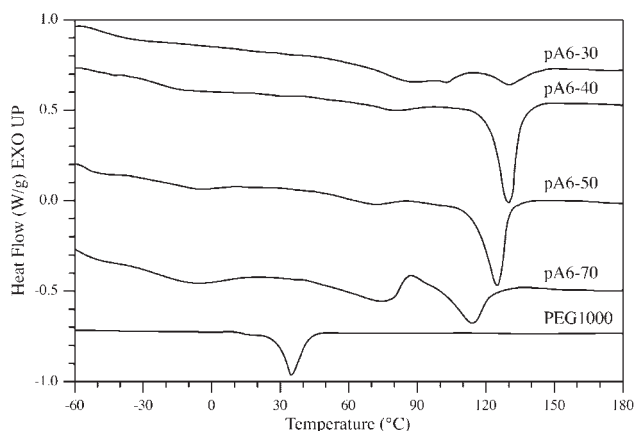


Figure 2. DSC traces of pA6-x polymer series (2<sup>nd</sup> heating cycle,  $10\text{ }^{\circ}\text{C}\cdot\text{min}^{-1}$  heating rate).

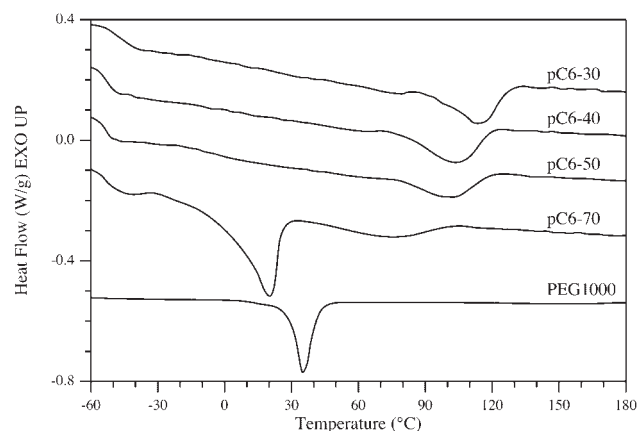


Figure 3. DSC traces of pC6-x polymer series (2<sup>nd</sup> heating cycle,  $10\text{ }^{\circ}\text{C}\cdot\text{min}^{-1}$  heating rate).



Table 4. Contact angles and surface free energy of poly(ether ester)s containing H-bonding unit with different PEG content (nd = not determined).

Sample	$\theta$		$\gamma_s^D$	$\gamma_s^H$	$\gamma_s^T$
	degrees				
	H <sub>2</sub> O	CH <sub>2</sub> I <sub>2</sub>			
pA4-30	54.5 ± 1.1	28.5 ± 0.5	37.5 ± 5.2	16.4 ± 5.2	53.9 ± 10.4
pA4-40	43.7 ± 0.1	17.2 ± 0.9	39.3 ± 5.6	23.1 ± 7.6	62.5 ± 13.3
pA4-50	37.0 ± 1.6	19.0 ± 0.2	38.4 ± 5.3	26.2 ± 7.6	64.6 ± 12.8
pA4-70	25.9 ± 1.9	22.5 ± 0.4	36.6 ± 5.3	32.8 ± 9.1	69.4 ± 14.4
pA6-30	89.0 ± 0.7	52.8 ± 1.3	30.7 ± 4.4	2.4 ± 1.3	33.1 ± 5.7
pA6-40	63.0 ± 2.8	29.3 ± 1.2	39.2 ± 5.5	21.1 ± 6.3	60.3 ± 11.8
pA6-50	50.2 ± 1.3	16.6 ± 2.7	40.8 ± 5.9	17.8 ± 5.9	58.6 ± 11.8
pA6-70	51.6 ± 4.8	14.6 ± 1.2	42.1 ± 5.7	14.4 ± 4.7	56.5 ± 10.5
pC6-30	81.1 ± 1.4	36.7 ± 2.2	38.6 ± 5.6	3.3 ± 1.8	41.9 ± 7.5
pC6-40	50.5 ± 0.7	26.7 ± 1.2	37.1 ± 5.6	19.0 ± 7.0	56.1 ± 12.6
pC6-50	24.0 ± 2.1	12.3 ± 0.7	38.6 ± 5.3	32.4 ± 8.9	71.0 ± 14.3
pC6-70	nd	14.1 ± 0.2	14.0 ± 0.2	nd	nd

(Table 4). Due to fast swelling, the contact angle of water was not measured on pC6-70 films.

As expected, in all cases the water contact angles decreased on increasing the polymer PEG content. The type of H-bonding affected the water contact angles. At comparable PEG contents, the contact angles of pC6-x poly(ether ester carbamate)s were always lower than those of pA6-x poly(ether ester amide)s. On the other hand, the pA6 contact angles were always higher than those of the pA4 polymers, demonstrating that the length of the polymethylene spacer between the H-bonding groups affects the polymer surface characteristics. The dependence of CH<sub>2</sub>I<sub>2</sub> contact angles on polymer structure showed a similar behavior.

The H-bonding ( $\gamma_s^H$ ) and dispersive ( $\gamma_s^D$ ) surface free energy contributions were calculated from the water and CH<sub>2</sub>I<sub>2</sub> contact angles (Table 4), according to a reported procedure.<sup>[19]</sup> The computed  $\gamma_s^D$  values were between 30 and 40 dyne · cm<sup>-1</sup>, independent of PEG content and H-bonding structure. However,  $\gamma_s^H$  values comprised a larger range (2–33 dyne · cm<sup>-1</sup>) and showed an almost linear dependence on the PEG content. The surface free energy  $\gamma_s^T$  followed the same trend, as expected, considering that it comprises the sum of  $\gamma_s^H$  and  $\gamma_s^D$ . These data confirm that the polymer surface hydrophilicity increases with PEG content, indicating that more PEG segments are exposed to the polymer surface as the PEG content increases.

### Equilibrium Swelling

The equilibrium swelling behavior of the prepared polymers was determined in PBS by measuring their weight increase at intervals up to 48 h. In all cases, the water uptake

leveled off after a few hours. The percent equilibrium swelling ratio (*ESR*) was evaluated from the experimental data as  $ESR = 100 \cdot (w_s - w_d) / w_d$ , where  $w_s$  and  $w_d$  are the sample weight in the swollen and in the dry state, respectively (Figure 4).

In general, *ESR* values increased with increasing PEG content but were in all cases lower than 20%. In order to verify whether the samples were at least partially soluble in water, a representative PEG-rich sample (pA4-70) was suspended in water. Analysis of both the solution and the insoluble residue indeed indicated that a 33% fraction containing 76 wt.-% PEG was soluble in water, whereas the insoluble fraction contained 62 wt.-% PEG. This result indicates that the polymer composition was not homogeneous.

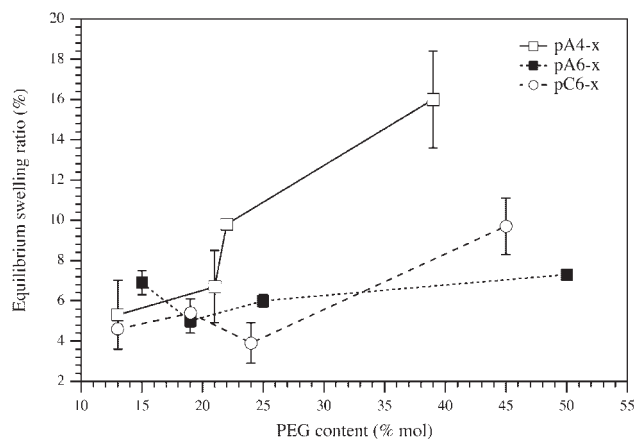


Figure 4. Equilibrium swelling ratio of poly(ether ester)s containing H-bonding units, in PBS at 37 °C for 48 h.

## Conclusions

Poly(ether ester)s containing H-bonding units and PEG segments can be prepared in good yields by  $\text{Ti}(\text{O}i\text{Bu})_4$  catalyzed bulk polycondensation of monomeric precursors containing H-bonding moieties with 1,4-butanediol/PEG1000 mixtures. The presence of strongly interacting, partially hydrophobic H-bonding units and of hydrophilic PEG segments afforded materials characterized by a significant tendency to phase separate. Both the thermal and the solubility properties of the polymers were modulated by varying the nature of the H-bonding units and the PEG content. Polymer bulk and surface hydrophilicity, important parameters in material biocompatibility, can be tuned by changing the amount of PEG segments, which are progressively exposed at the polymer surface. The reported characteristics and the presence of hydrolyzable ester bonds make the prepared materials very promising for application in the biomedical-pharmaceutical field.

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