Amphipathic block copolymers with two polypeptide blocks: Synthesis and structural study of poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymers

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AB block copolymers of poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine (KtSa) were synthesized and studied by X-ray diffraction. In order to obtain copolymers with a polydispersity small enough to allow the formation of mesophases, the first block of poly(N^{ε}-trifluoroacetyl-L-lysine) was fractionated before using it as a macromolecular initiator of the polymerization of the second block of polysarcosine. Block copolymers of KtSa exhibit lamellar mesophases in the solid state and in concentrated aqueous solution. Each sheet of the lamellar structure results from the superposition of two layers: one formed by the hydrophilic polysarcosine chains in a disordered conformation, the other formed by the hydrophobic poly(N^{ε}-trifluoroacetyl-L-lysine) chains in an α-helix type conformation arranged in a hexagonal array and tilted. The influence of the water content of the mesophase and of the composition of the copolymers on the structural parameters of the lamellar structure was analysed and it was shown that the angle of tilt of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices increases with both the water content of the mesophases and the length of the polysarcosine chains.

(Keywords: block copolymers; polypeptides; mesomorphic structure; conformation; synthesis; X-ray diffraction)

INTRODUCTION

In order to obtain biocompatible polymeric materials, some years ago we synthesized AB block copolymers with vinyl and peptide blocks and studied their structure by X-ray diffraction and infra-red spectroscopy[1–5]. Then we tested the haemocompatibility of the copolymers by studying their effect upon whole blood and its specific constituents (erythrocytes, leukocytes and platelets), their influence on the blood coagulation process by thromboelastography and their possible toxicity by growing living cells on copolymer films[6]. The main results of this study were the following: the copolymers with polyvinyl and polypeptide blocks exhibit a microphase separated lamellar structure[1–5] and the addition of a polypeptide block to a vinyl polymer improves the haemocompatibility of the polymer; furthermore the influence of the polymer on the main blood constituents varies with both the nature of the polypeptide block and the nature of the blood constituents tested[6].

To evaluate the influence of the nature of the polypeptide blocks and of the microphase separated structure of AB copolymers on haemocompatibility, we have synthesized amphipathic block copolymers with hydrophilic and hydrophobic polypeptide blocks[7]. In this paper we first report the synthesis of amphipathic block copolymers of poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine (KtSa) consisting of a hydrophobic block of poly(N^{ε}-trifluoroacetyl-L-lysine) (Kt) and a hydrophilic block of polysarcosine (Sa). Then we describe the structural study by X-ray diffraction of the mesophases exhibited by block copolymers of KtSa and the respective influence of the factors governing the geometrical parameters of the structure of the mesophases and of the dry copolymers obtained by evaporation of the solvent of the mesophases.

EXPERIMENTAL

Materials

Reagents. Mercaptoethanol, trifluoroacetic anhydride, L-lysine, sarcosine and *N*-hexylamine were purchased from Fluka in the best grade available and purified by the usual methods.

Solvents. Tetrahydrofuran (THF) and *N*,*N*-dimethylformamide (DMF) were purified as already described[5].

Monomers. N^{ε}-trifluoroacetyl-L-lysine was prepared from L-lysine and ethylthiotrifluoroacetate[8], which was synthesized from mercaptoethanol and trifluoroacetic anhydride[9].

N-Carboxyanhydrides (NCA). The *N*-carboxysarcosine anhydride (Sa-NCA) and the *N*-carboxytrifluoroacetyl-L-lysine anhydride (Kt-NCA) were prepared by the action of phosgene on sarcosine and N^{ε}-trifluoroacetyl-L-lysine in THF solution[10].

Synthesis of block copolymers

Polymerization of the first block. The first block of poly(N^{ε}-trifluoroacetyl-L-lysine) (Kt) was prepared at room temperature in DMF solution, with agitation, by polymerization of the Kt-NCA, using *N*-hexylamine as initiator. After precipitation with water, the poly(N^{ε}-

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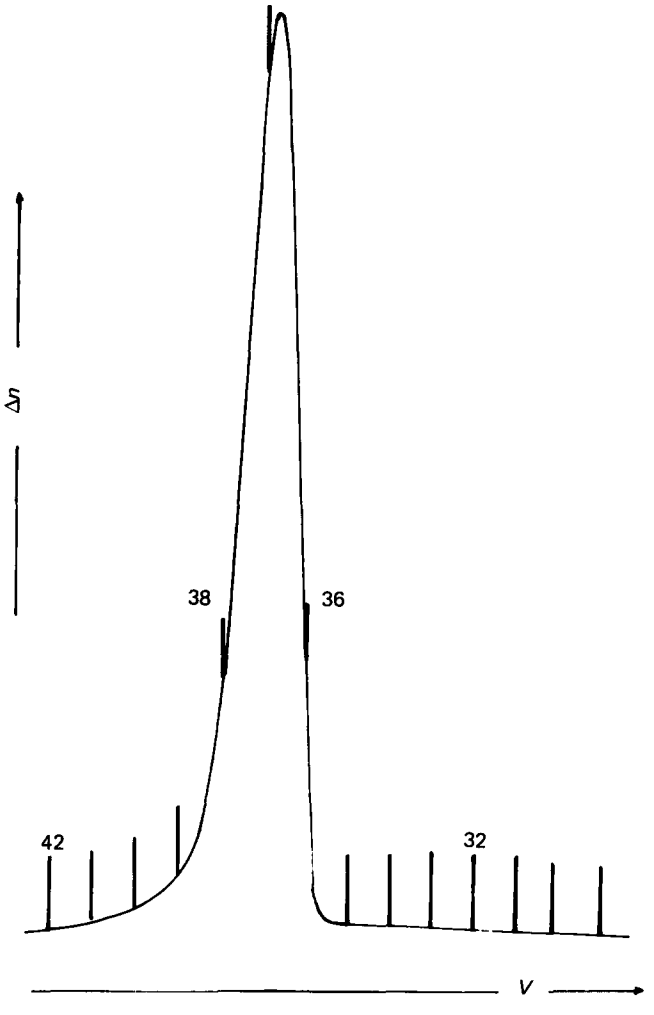
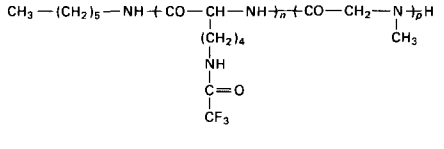


Figure 1 G.p.c. curve of the Kt block used for the synthesis of the KtSa copolymers: g.p.c. (Waters) with five Styragel columns (10^6 Å, 10^5 Å, 10^4 Å, 10^3 Å and 60 Å); THF system at 25°C. The refractive index difference Δn is plotted *versus* elution volume V, both in arbitrary units

trifluoroacetyl-L-lysine) was fractionated by the system DMF(solvent)/water(non-solvent) in order to obtain fractions with a dispersity small enough to allow the formation of mesophases by KtSa copolymers. The low dispersity of the Kt block was evidenced by g.p.c. as shown in *Figure 1*.

Polymerization of the second block. Fractions of poly(N^{ε}-trifluoroacetyl-L-lysine) were used as macromolecular initiators of the polymerization of the Sa-NCA. The polymerization was performed at room temperature, in DMF solution, with agitation.

The KtSa copolymer was precipitated with ether. The homopolysarcosine possibly formed was eliminated by precipitation with acetone and the homopoly(N^{ε}-trifluoroacetyl-L-lysine) by precipitation with water. The structure of the KtSa copolymer is as follows:



Characterization of block copolymers

The number average molecular weights of the poly(N^{ε}-trifluoroacetyl-L-lysine) block (Kt) and of the KtSa copolymers were determined by osmometry in acetone at 20°C (Mechrolab 503).

The composition of poly(N^{ε}-trifluoroacetyl-L-lysine) in the copolymers was determined by measuring their optical rotatory power in dichloroacetic acid and comparing it with that for the homopoly(N^{ε}-trifluoroacetyl-L-lysine) obtained in the same solvent, taking advantage of the fact that polysarcosine has no asymmetric carbon atom.

The molecular weights and compositions of the KtSa copolymers studied by X-ray diffraction are given in *Table 1*.

Preparation of mesomorphic gels

The KtSa copolymers were dissolved in water and when total homogeneity was realized (if necessary, after heating at 60°C) the concentration was adjusted by evaporation of excess solvent at a slow rate. After X-ray experiments the concentration of each gel was determined.

Structural determination

The mesomorphic structure of the KtSa copolymers and the conformation of the polypeptide chains were studied in water solution and in the dry state by X-ray diffraction and in the dry state by infra-red spectroscopy. X-ray diffraction studies were performed with a Guinier type focusing camera, using monochromatic X-rays ($CuK\alpha_1$), giving a linear collimation and operating under vacuum.

STRUCTURE OF COPOLYMERS

Block KtSa copolymers with a hydrophobic poly(N^{ε}-trifluoroacetyl-L-lysine) block (Kt) and a hydrophilic polysarcosine block (Sa) exhibit mesophases in good solvents of polysarcosine such as water for solvent concentrations smaller than about 60 wt%.

The study by X-ray diffraction and infra-red spectroscopy of block KtSa copolymers with compositions in polysarcosine between 25 and 73% has shown that they exhibit a periodic lamellar structure both in the mesophases and in the dry state after evaporation of the solvent of the mesophase at a slow rate.

We will first describe the structure and then justify it.

Description of the structure

The lamellar structure results from the equidistant superposition of parallel sheets, Each elementary sheet having a thickness d consists of two layers: one layer of thickness d_A contains the hydrophilic polysarcosine chains in a coiled conformation and water; the other layer of thickness d_B contains the hydrophobic poly(N^{ε}-trifluoroacetyl-L-lysine) chains in an α-helix confor-

Table 1 Molecular characteristics of the KtSa copolymers used for X-ray diffraction studies[a]

Copolymer	$\bar{M}_n$ (Kt)	Sa content (%)	$\bar{M}_n$ (Sa)
KtSa 21	14100	42.6	10500
KtSa 25	14100	72.3	36900
KtSa 26	14100	25.6	4850

[a] Kt = poly(N^{ε}-trifluoroacetyl-L-lysine), Sa = polysarcosine

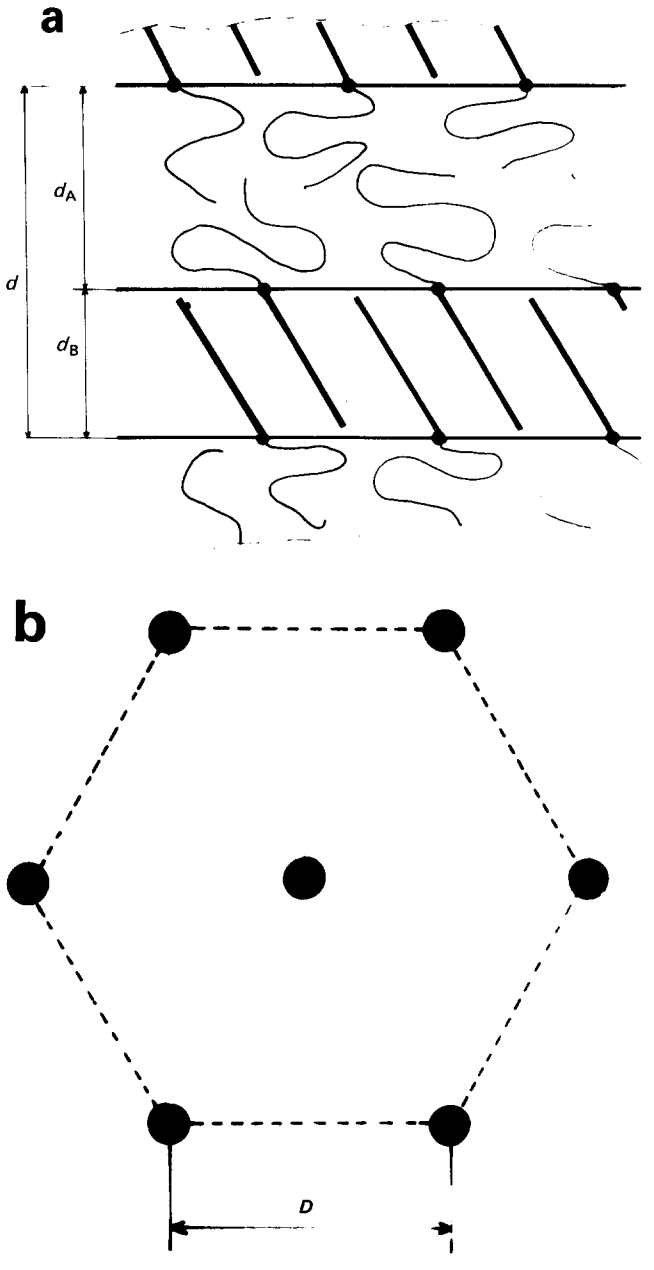


Figure 2 (a) Schematic representation of the lamellar structure of block poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymers: d = intersheet spacing, d_A = thickness of the layer containing the polysarcosine chains, d_B = thickness of the layer containing the poly(N^{ε}-trifluoroacetyl-L-lysine) helices. (b) Hexagonal array of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices: D = distance between the axis of two helices

mation, with the helix axis tilted on the plane of the lamellae and assembled in a hexagonal array (in a plane perpendicular to the axis of the helices), whose lattice parameter is identical to that of the anhydrous homopoly(N^{ε}-trifluoroacetyl-L-lysine) and independent of the water content of the mesophase (*Figure 2*).

The characteristic parameters of the lamellar structure are as follows:

(a) The total thickness d of a sheet (*Figure 2a*) and the lattice parameter D (*Figure 2b*) of the hexagonal array formed by the poly(N^{ε}-trifluoroacetyl-L-lysine) helices (distance D between the Kt helices) can both be directly deduced from X-ray patterns.

(b) The thicknesses d_A and d_B of the polysarcosine and poly(N^{ε}-trifluoroacetyl-L-lysine) layers and the average surface S available for a molecule at the interface between the two layers are calculated using formulae (1), (2) and (3) based on simple geometrical considerations:

$$d = d_A + d_B \tag{1}$$

$$d_B = \left(1 + \frac{cX_A v_A + (1-c)\phi_A v_S}{c(1-X_A)v_B + (1-c)\phi_B v_S}\right)^{-1} \tag{2}$$

$$S = 2M_B v_B / N d_B \tag{3}$$

(c) The surface Σ available to a poly(N^{ε}-trifluoroacetyl-L-lysine) helix is calculated from D using formula (4):

$$\sum = (\sqrt{3}/2)D^2 \tag{4}$$

(d) The projection h on the helix axis of the distance between two (N^{ε}-trifluoroacetyl-L-lysine) residues is given by formula (5):

$$h = (2/\sqrt{3})mv_B/ND^2 \tag{5}$$

(e) The average length $\bar{L}$ of a poly(N^{ε}-trifluoroacetyl-L-lysine) helix is given by formula (6):

$$\bar{L} = hP_n \tag{6}$$

(f) The angle θ between the direction perpendicular to the interface and the direction of the axis of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices is given by formulae (7) and (8):

$$\cos\theta = d_B/\bar{L} \tag{7}$$

$$\cos\theta = 2\sum/S \tag{8}$$

In these equations the notation is as follows:

c	copolymer concentration (in g per g in solution)
X_A	weight fraction of the polysarcosine block in the copolymer
X_B	weight fraction of the poly(N^{ε}-trifluoroacetyl-L-lysine) block in the copolymer
v_A	specific volume of the polysarcosine block: $v_A = 0.76$
v_B	specific volume of the poly(N^{ε}-trifluoroacetyl-L-lysine) block: $v_B = 0.705$
v_S	specific volume of the solvent
ϕ_A, ϕ_B	partition coefficients of the solvent ($\phi_A + \phi_B = 1$); for water $\phi_A = 1$
M_B	number average molecular weight of the poly(N^{ε}-trifluoroacetyl-L-lysine) block
N	Avogadro's number
m	molecular weight of the N^{ε}-trifluoroacetyl-L-lysine unit: $m = 224$
P_n	number average degree of polymerization of the poly(N^{ε}-trifluoroacetyl-L-lysine) block

Justification of the structure

Lamellar character of the structure. The lamellar character of the structure is demonstrated by X-ray diffraction: namely by the presence of a set of sharp lines with Bragg spacings in the ratio 1:2:3:4:5 in the very-low-angle region of the X-ray patterns (*Figure 3*).

Hexagonal packing of the poly(N^{ε}-trifluoroacetyl-L-lysine) chains. The hexagonal packing of the poly(N^{ε}-trifluoroacetyl-L-lysine) chains is also established by X-ray diffraction: namely by the presence of a set of three sharp lines with Bragg spacings in the ratio $1:\sqrt{3}:\sqrt{4}$ in

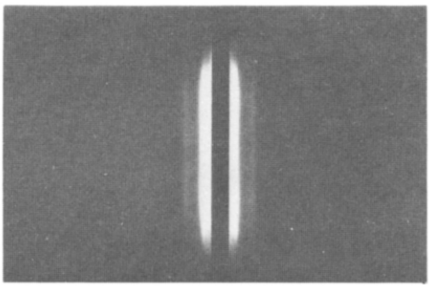


Figure 3 Very-low-angle region of the X-ray diagrams (characteristic of the lamellar structure) obtained with the KtSa 21 copolymer (only the two first orders of diffraction are visible)

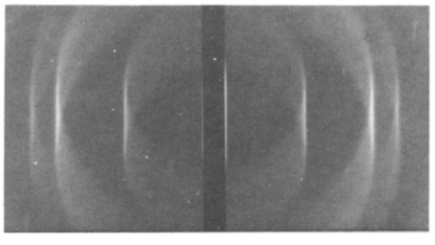


Figure 4 Low-angle region of the X-ray patterns (characteristic of the hexagonal packing of the Kt helices) obtained with the KtSa 21 copolymer

the low-angle region of the X-ray patterns (*Figure 4*). Furthermore, the value found for the hexagonal lattice parameter $D = 14.4$ Å is identical to that obtained for homopoly(N^{ε}-trifluoroacetyl-L-lysine).

α-Helix type conformation of the poly(N^{ε}-*trifluoroacetyl*-L-*lysine*) *chains.* The α-helix type conformation of the poly(N^{ε}-trifluoroacetyl-L-lysine) chains is demonstrated by infra-red spectroscopy (bands amide I and amide II at 1655 and 1545 cm^{-1} respectively) and by X-ray diffraction (region of low angles, *Figure 4*). From the value of the hexagonal lattice parameter D formed by the Kt helices and the molecular characteristics of the poly(N^{ε}-trifluoroacetyl-L-lysine) block, the projection h on the helix axis of the distance between two N^{ε}-trifluoroacetyl-L-lysine residues was calculated by formula (5) and found to be $h = 1.46 \pm 0.2$ Å, in good agreement with an α-type helix.

Tilt of the poly(N^{ε}-*trifluoroacetyl*-L-*lysine*) *helices.* The average length L ($l = hP_n$) of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices is higher than the thickness d_B of the hydrophobic layer for any copolymer studied and any water content. Therefore, to enter the layer of thickness d_B the poly(N^{ε}-trifluoroacetyl-L-lysine) helices must be folded or tilted.

We have previously shown[1-5] that AB type vinyl–peptide block copolymers with a vinylic block of polybutadiene or polystyrene and a peptidic block of poly(γ-benzyl-L-glutamate) or (poly(N^{ε}-benzyloxycarbonyl-L-lysine) exhibit a lamellar structure where the polypeptide chains in an α-helix conformation are hexagonally packed and generally folded. Furthermore the peptidic helices fold after an integral number of repeat units along the helix axis. The numbers of folds are integer values that for a given copolymer are independent of the solvent concentration of the mesophases, but vary in a discontinuous way with the nature of the vinylic and peptidic blocks, the molecular weight of the vinylic and peptidic blocks and the composition of the copolymers[5]. For AB type vinyl–peptide copolymers with folded polypeptide helices, the thickness d_B of the layer containing the polypeptide helices is independent of the solvent concentration of the mesophase. Also the lattice parameter D of the hexagonal lattice of the helices, the average surface Σ occupied by a helix and the specific surface S at the interface all increase with the solvent content of the mesophase (the ratio S/Σ being independent of the solvent content)[5]. Such a behaviour is illustrated by *Figure 5* corresponding to the polystyrene–poly(benzyl glutamate) copolymer SG 14 with a molecular weight of the polystyrene block of 25 000, a polypeptide composition of 47% and where the polypeptide chains are folded twice[5].

In contrast, for amphiphatic KtSa copolymers (*Figures 6–8*), when the water content increases, the thickness d_B of the layer containing the poly(N^{ε}-trifluoroacetyl-L-lysine) helices decreases and the ratio L/d_B (which characterizes

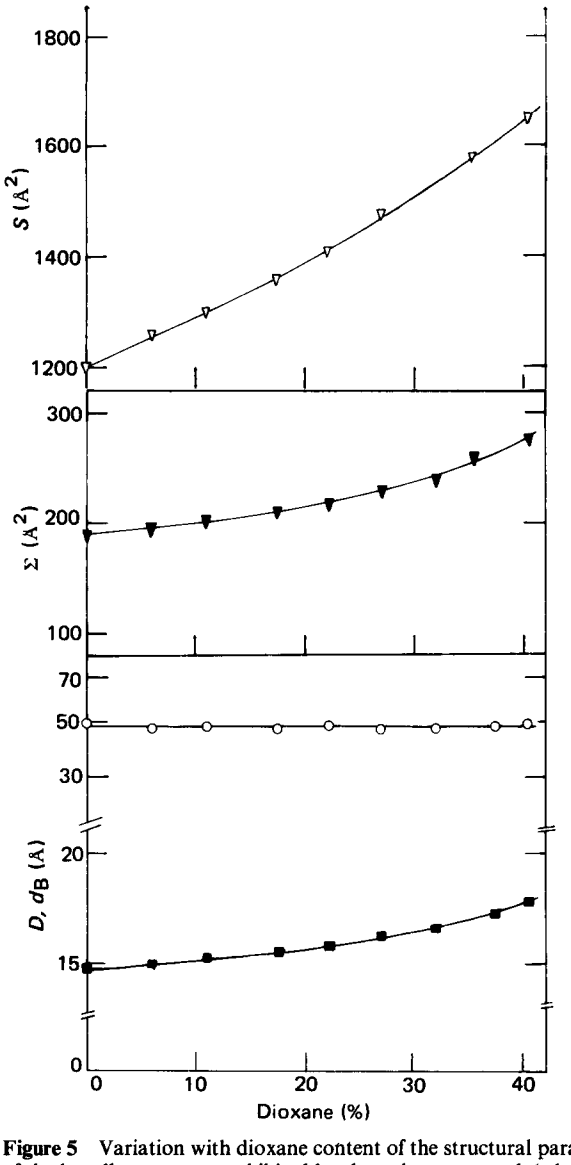


Figure 5 Variation with dioxane content of the structural parameters of the lamellar structure exhibited by the polystyrene–poly(γ-benzyl-L-glutamate) copolymer SG 14 containing 47% of polypeptide[5]: (○) d_B = thickness of the polypeptide layer; (■) D = parameter of the hexagonal lattice of the polypeptide helices; (▼) Σ = average surface occupied by a polypeptide helix; (▽) S = specific surface

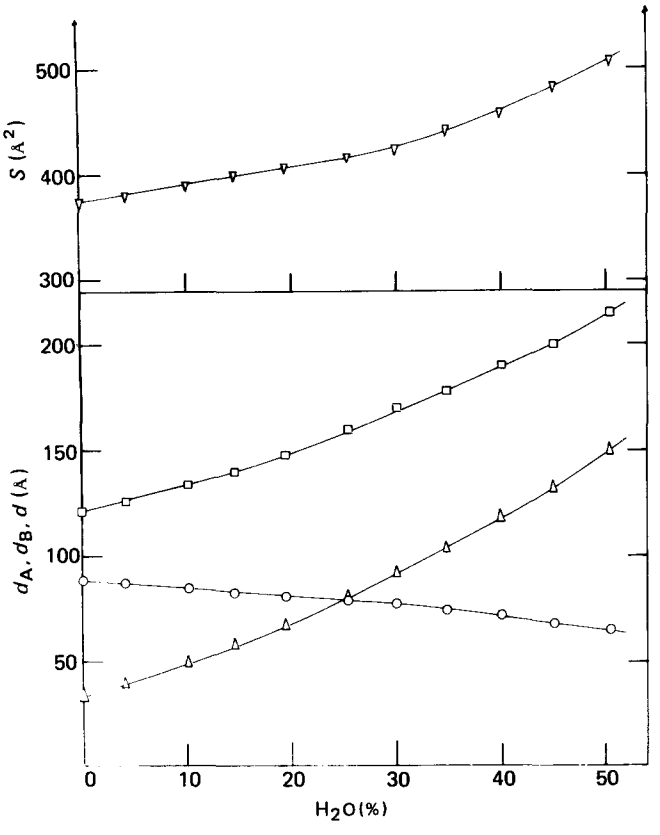


Figure 6 Variation with water content of the structural parameters of the lamellar structure exhibited by the poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymer KtSa 26 containing 25.6% of polysarcosine: (□) d=intersheet spacing; (△) d_A=thickness of the polysarcosine layer; (○) d_B=thickness of the poly(N^{ε}-trifluoroacetyl-L-lysine) layer; (▽) S=specific surface

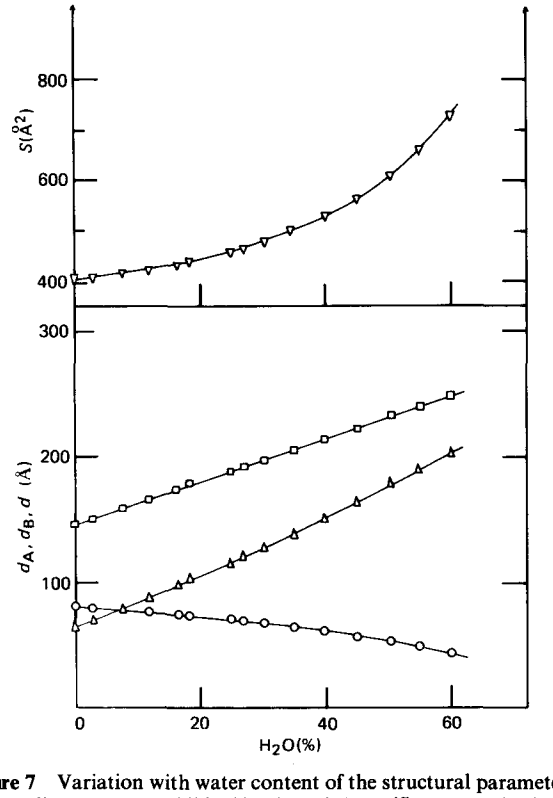


Figure 7 Variation with water content of the structural parameters of the lamellar structure exhibited by the poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymer KtSa 21 containing 43.6% of polysarcosine: (□) d=intersheet spacing; (△) d_A=thickness of the polysarcosine layer; (○) d_B=thickness of the poly(N^{ε}-trifluoroacetyl-L-lysine) layer; (▽) S=specific surface

the potential folding of the helices) increases continuously (*Figure 9*). At the same time, the lattice parameter D of the hexagonal array formed by the helices (*Figure 10*) is independent of the water content and, for all copolymers studied, remains equal to 14.4 Å, that is the value found for dry homopoly(N^{ε}-trifluoroacetyl-L-trifluoroacetyl-L-lysine). Furthermore, for all copolymers studied, the average surface Σ available for a poly(N^{ε}-trifluoroacetyl-L-lysine) helix is independent of the water content of the system and remains equal to 180 Å^2 as in the dry homopoly(N^{ε}-trifluoroacetyl-L-lysine) (*Figure 10*). The average surface S per molecule at the interface increases with the water content (*Figures 6–8*) of the system, leading to a decrease of the ratio Σ/S. So if there were a folding of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices, the number of folds v ($v+1=L/d_B$) would increase continuously with the water content (L/d_B increases continuously) (*Figure 9*), the folds would not take place after an integer multiple of repeat units along the helix axis and the number of folds would not take integer values. Therefore, it is much more reasonable to explain the behaviour of the KtSa copolymers by the existence of an angle of tilt θ between the direction of the axis of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices and that perpendicular to the interface.

In the absence of water, the value of the angle of tilt θ is determined by the ratio of the surface Σ occupied by a hexagonally packed helix of poly(N^{ε}-trifluoroacetyl-L-

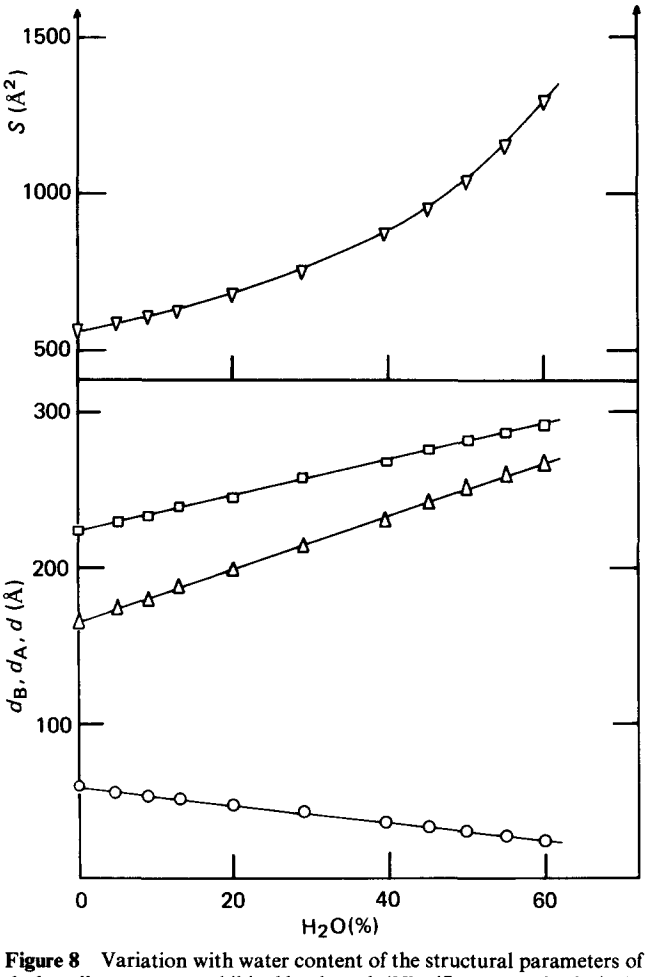


Figure 8 Variation with water content of the structural parameters of the lamellar structure exhibited by the poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymer KtSa 25 containing 74.4% of polysarcosine: (□) d=intersheet spacing; (△) d_A=thickness of the polysarcosine layer; (○) d_B=thickness of the poly(N^{ε}-trifluoroacetyl-L-lysine) layer; (▽) S=specific surface

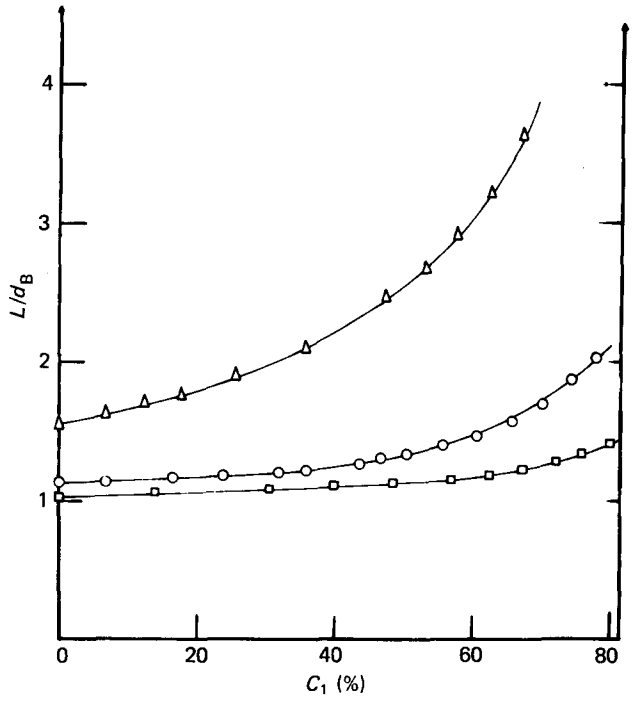


Figure 9 Variation with the water content C_1 of the hydrophilic polysarcosine layer of the ratio L/d_B (L=length of the Kt helices; d_B=thickness of the Kt layer); (□) KtSa 26; (○) KtSa 21; (△) KtSa 25. The water content is given by

$$C_1 = \frac{1-C}{1-C+CX_A} \times 100$$

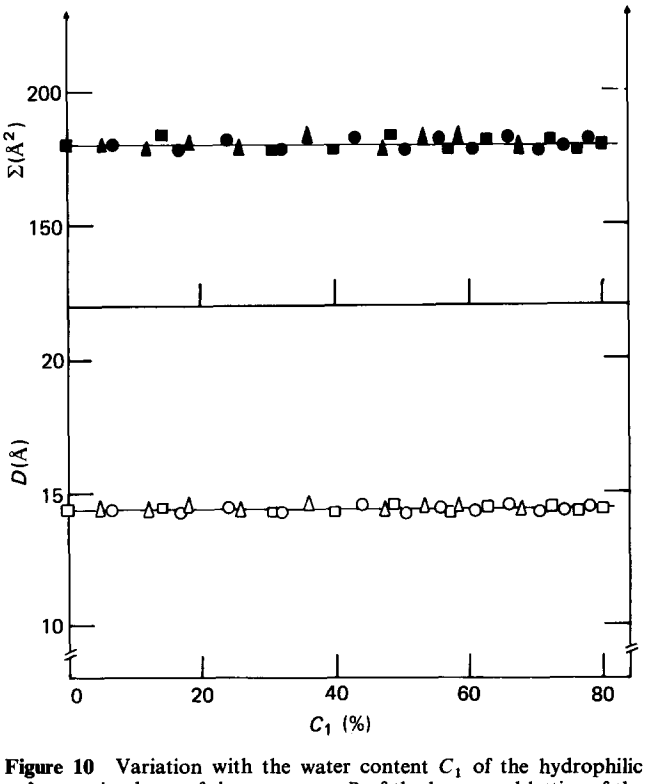


Figure 10 Variation with the water content C_1 of the hydrophilic polysarcosine layer of the parameter D of the hexagonal lattice of the helices of poly(N^ε-trifluoroacetyl-L-lysine) (Kt) and of the surface Σ per helix of Kt: (■, □) KtSa 26; (●, ○) KtSa 21; (▲, △) KtSa 25. The water content C_1 is defined in *Figure 9*

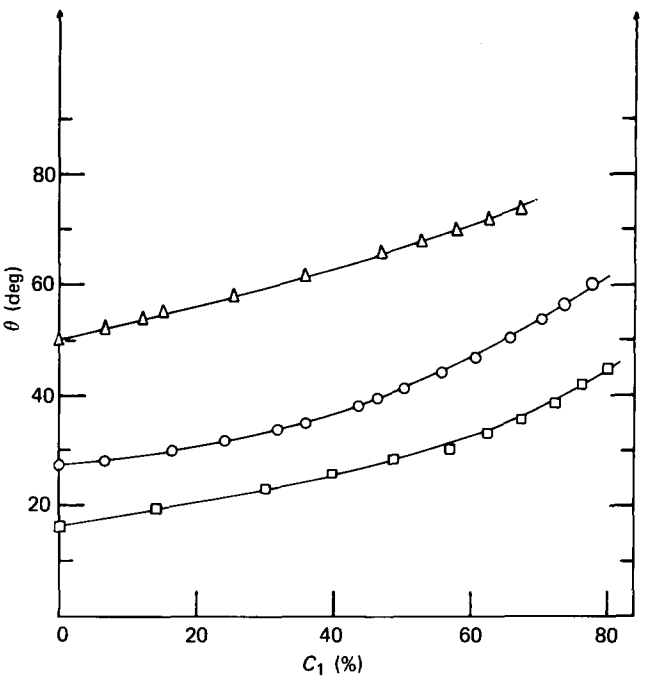


Figure 11 Variation with the water content C_1 of the hydrophilic polysarcosine layer of the angle of tilt θ of the poly(N^ε-trifluoroacetyl-L-lysine) helices: (□) KtSa 26; (○) KtSa 21; (△) KtSa 25. The water content C_1 is defined in *Figure 9*

lysine) and the surface S necessary for a coiled polysarcosine chain with a fixed molecular weight (equation (8)). When water is added to the system, the hydrophilic polysarcosine chains swell, the surface S for a molecule at the interface increases and to occupy all of the available surface the poly(N^ε-trifluoroacetyl-L-lysine) helices are forced to increase their angle of tilt, inducing a decrease of the thickness d_B of the hydrophobic poly(N^ε-trifluoroacetyl-L-lysine) layer.

Influence of the water content

Figures 6–11 illustrate the influence of the water content on the geometrical parameters of the lamellar structure exhibited by amphipatic KtSa copolymers. When the water concentration increases:

(a) the total thickness d of the sheets increases (*Figures 6–8*);

(b) the thickness d_A of the layer containing the hydrophilic polysarcosine chains increases (*Figures 6–8*);

(c) the thickness d_B of the layer containing the hydrophobic poly(N^ε-trifluoroacetyl-L-lysine) helices decreases (*Figure 6–8*);

(d) the average surface S available for a molecule at the interface increases (*Figures 6–8*);

(e) the parameter D of the hexagonal array formed by the poly(N^ε-trifluoroacetyl-L-lysine) helices remains constant and therefore the surface for a poly(N^ε-trifluoroacetyl-L-lysine) helix remains constant (*Figure 10*);

(f) the angle of tilt θ of the poly(N^ε-trifluoroacetyl-L-lysine) helices increases (*Figure 11*).

Influence of the composition of the copolymer

The study of a set of three copolymers, KtSa 26, KtSa 21 and KtSa 25, with a hydrophobic block of poly(N^ε-trifluoroacetyl-L-lysine) with a constant mole-

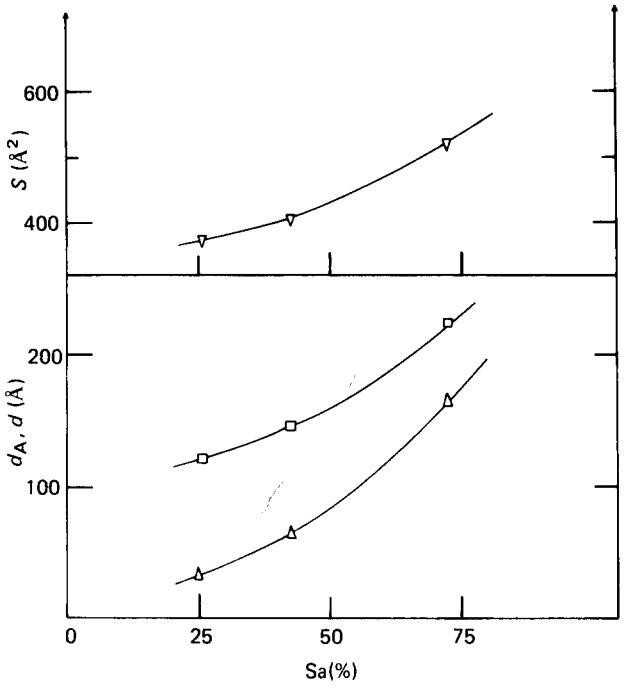


Figure 12 Variation of the geometrical parameters of the lamellar structure of dry KtSa copolymers with the polysarcosine content of the copolymers: (□) d = intersheet spacing; (△) d_A = thickness of the polysarcosine layer; (▽) S = specific surface

cular weight (14 100) but with increasing content of polysarcosine has allowed us to establish the influence of the composition of the copolymers on the geometrical parameters of the lamellar structure. These copolymers were obtained by polymerization of different amounts of Sa-NCA at the end of samples of poly(N^{ε}-trifluoroacetyl-L-lysine) with a number average molecular weight of 14 100. *Figures 12* and *13* illustrate the results obtained in the case of dry copolymers. When the content of polysarcosine of the copolymer increases:

(a) the total thickness d of the sheets, the thickness d_A of the layer containing the polysarcosine chains and the surface S per molecule at the interface all increase (*Figure 12*);

(b) the thickness d_B of the layer containing the hydrophobic poly(N^{ε}-trifluoroacetyl-L-lysine) helices decreases (*Figure 13*);

(e) the parameter D of the hexagonal array of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices and the surface occupied by a helix both remain constant (*Figure 13*);

(d) the angle of tilt θ of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices increases (*Figure 13*).

It is easy to understand the increase of the tilt angle of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices. When the molecular weight of the polysarcosine chains increases, the surface S at the interface occupied by a coiled chain increases, and the poly(N^{ε}-trifluoroacetyl-L-lysine) helix is forced to increase its angle of tilt to occupy the surface available.

CONCLUDING REMARKS

In this paper, we have shown that it is possible to synthesize amphipathic block copolymers with two polypeptide blocks exhibiting a low polydispersity allowing the formation of a well developed original lamellar structure. In this lamellar structure, the hydrophilic polypeptide chains are in a coiled conformation while the hydrophobic polypeptide chains adopt an α-helix conformation, are arranged on a hexagonal array and are tilted. Furthermore the angle of tilt of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices increases with both the water content of the mesophases and the length of the polysarcosine chains.

It is interesting to compare the behaviour of the hydrophobic polypeptide chains when they are linked to different kinds of polymeric chains. Until now we have studied three types of copolymers containing hydrophobic polypeptide chains: (i) copolymers with a hydrophobic nonpolar polyvinyl chain of polystyrene or polybutadiene and a hydrophobic polypeptidic chain[1-5] such as poly(γ-benzyl-L-glutamate) or poly(benzyloxycarbonyl-L-lysine); (ii) copolymers with a hydrophilic saccharidic chain and a hydrophobic polypeptidic chain[11]; and (iii) copolymers with a hydrophilic polysarcosine chain and a hydrophobic polypeptidic chain. The three types of copolymers exhibit lamellar structures in which the hydrophobic polypeptidic chains adopt an α-helix conformation and

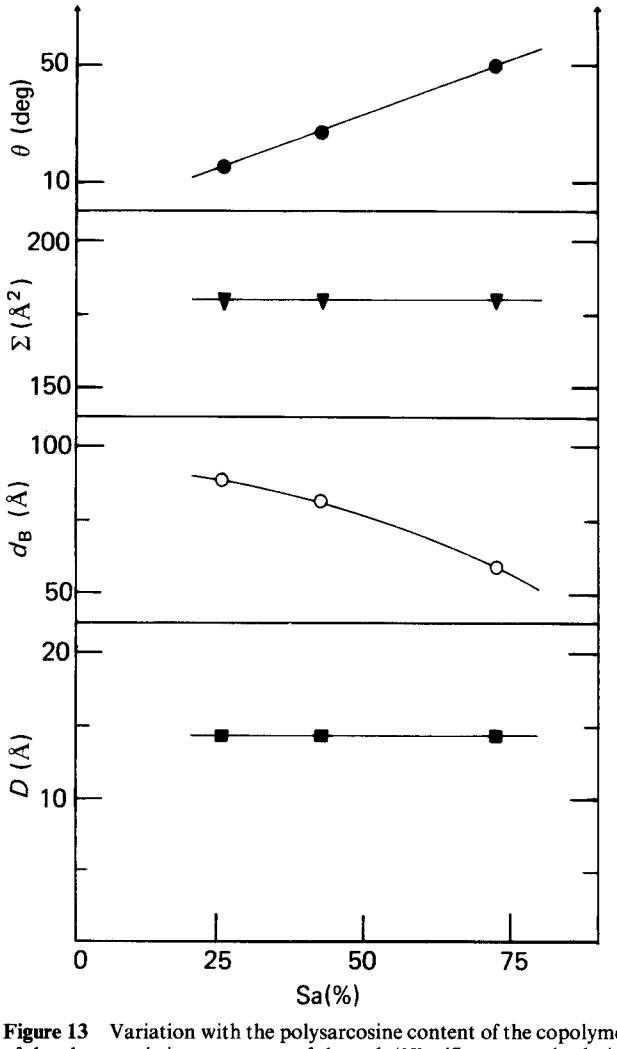


Figure 13 Variation with the polysarcosine content of the copolymers of the characteristic parameters of the poly(N^{ε}-trifluoroacetyl-L-lysine) chains in the case of dry copolymers: (■) D = parameter of the hexagonal lattice of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices; (○) d_B = thickness of the poly(N^{ε}-trifluoroacetyl-L-lysine) layer; (▼) Σ = surface occupied by a poly(N^{ε}-trifluoroacetyl-L-lysine) helix; (●) θ = angle of tilt of the axis of the poly(N^{ε}-trifluoroacetyl-L-lysine) helices

are arranged in a hexagonal array. In copolymers with saccharidic and peptidic blocks, the polypeptide helices are perpendicular to the interface between the hydrophilic and hydrophobic layers and the length of the helices governs the thickness of the hydrophobic layer[11]. In copolymers with vinylic and peptidic blocks the polypeptide helices are also perpendicular to the interface but the polypeptidic chains are generally folded[5]. In copolymers with hydrophilic and hydrophobic polypeptidic blocks, the polypeptide helices are tilted. Therefore, the nature of the other block (saccharidic, vinylic or hydrophilic polypeptidic) does not change the conformation of the hydrophobic polypeptidic chains but determines their detailed organization in the hydrophobic layer and this detailed organization is related to the surface at the interface occupied by the other type of chains.

For biomedical applications, the knowledge of the composition of the surface of polymeric materials exhibiting phase separation at the molecular level is very important as it largely influences the haemocompatibility of the material. So the study by X-ray photoelectron spectroscopy of the composition of the surface of films of poly(N^{ε}-trifluoroacetyl-L-lysine)–polysarcosine copolymers has been performed and the results of this study will be reported in a forthcoming paper.

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