DOI: 10.1002/masy.200850108

Synthesis of Amphiphilic ABCBA-Type Pentablock Copolymer from Consecutive ATRPs and Self-Assembly in Aqueous Solution

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Summary: A novel amphiphilic ABCBA-type pentablock copolymer with properties that are sensitive to temperature and pH, poly(2-dimethylaminoethyl methacrylate)-*block*-poly(2,2,2-trifluoroethyl methacrylate)-*block*-poly(ε-caprolactone)-*block*-poly(2,2,2-trifluoroethyl methacrylate)-*block*-poly(2-dimethylaminoethyl methacrylate) (PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA), was synthesized via consecutive atom transfer radical polymerizations (ATRPs). The copolymers obtained were characterized by gel permeation chromatography (GPC) and ^{1}H nuclear magnetic resonance (NMR) spectroscopy, respectively. The aggregation behaviors of the pentablock copolymers in aqueous solution with different pH (pH = 4.0, 7.0 and 8.5) were studied. Transmission electron microscopic images revealed that spherical micelles from self-assembly of the pentablock copolymer were prevalent in all cases. The mean diameters of these micelles increased from 34, 46, to 119 nm when the pH of the aqueous solution decreased from 8.5, 7.0, to 4.0, respectively.

Keywords: amphiphilic copolymer; ATRP; block copolymer; multiblock copolymer; self-assembly

Introduction

Amphiphilic block copolymers with different architectures and chemical compositions that self-assemble into micelles and gels in response to environmental stimuli are an important class of materials with a large number of applications, including drug delivery systems, gene therapy, adaptive lubricants, and other 'smart' surface coatings.[1–8] Therefore, the synthesis of block copolymers has been very intensively studied, and the recent advances in 'living'/controlled radical polymerization (LRP) techniques have led to the facile synthesis of well-defined block copolymers with a wide range of functional monomers. For example, nitroxide-mediated polymerization (NMP),[9–11] atom transfer radical polymerization (ATRP),[12–19] and reversible addition–fragmentation chain transfer (RAFT)[20–25] have been used to synthesize well-defined polymeric materials with various architectures. Since the end-groups remain active in LRPs, synthesis of block copolymers with a range of functionalities and architectures is one of the most interesting phenomenons to study. Multiblock copolymers with hydrophilic and hydrophobic segments may have ideal biomedical properties and applications, which draws much attention to their preparation.[26] Among the available LRP methods, ATRP has proven to be a powerful LRP technique for the synthesis of well-defined block copolymers, and it can also be used for the synthesis of multiblock copolymers that cannot be prepared by conventional ionic polymerizations.[27]

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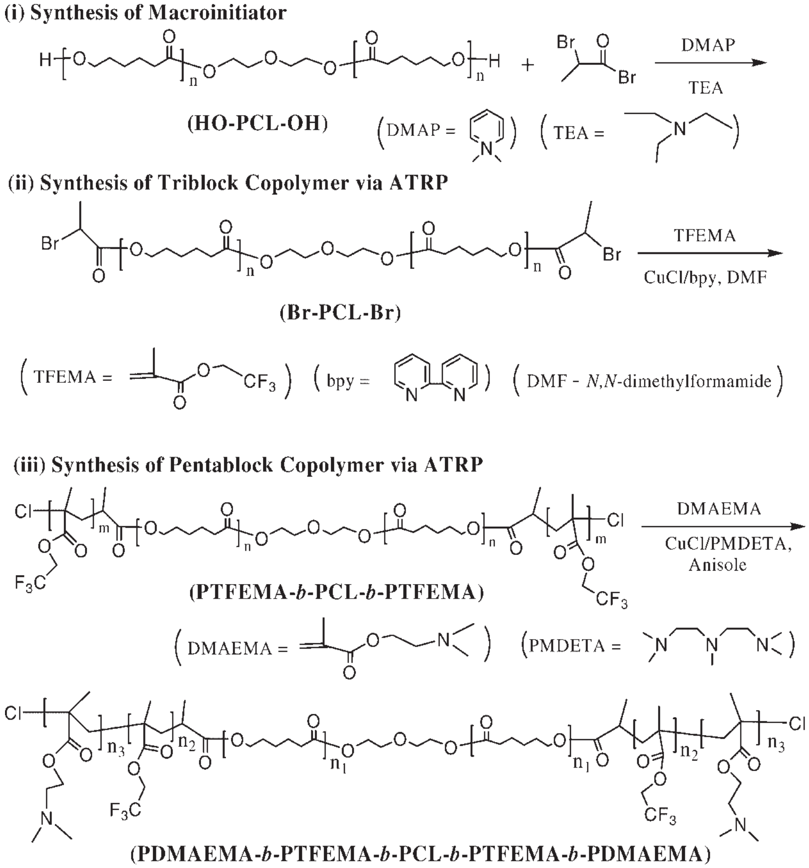
Among the family of amphiphilic block copolymers, the hydrophilic poly(2-(dimethylamino)ethyl methacrylate) (PDMAEMA) block is one of only a few polymers with properties that are sensitive to temperature and pH. It exhibits a low critical solution temperature (LCST) in the range of 38–40 °C and pH sensitivity characterized by a critical point at pH = 5.4.[28] The temperature-sensitive solubility of PDMAEMA in water also renders it potentially applicable in fields such as drug delivery systems, sensors, etc. A number of excellent works about amphiphilic diblock or triblock copolymers with PDMAEMA as a hydrophilic block, such as PSMA-*b*-PDMAEMA,[29] PtBMA-*b*-PDMAEMA,[30] PDMAEMA-*b*-PMMA-*b*-PDMAEMA[31] and PS-*b*-PDMAEMA,[32] have been reported. 2,2,2-Trifluoroethyl methacrylate (TFEMA) as a monomer has excellent water repellency because it contains fluorine in its side chain. PTFEMA is used in various coating applications because of its excellent heat and chemical resistance, low refractive index, and weatherability properties. As far as we know, however, the pentablock copolymer using PDMAEMA as hydrophilic block and using poly(ε-caprolactone) (PCL) with good drug permeability[33] and PTFEMA as hydrophobic blocks has not been reported until now. Thus, in this study, we synthesized a pentablock copolymer with a biodegradable PCL block and a hydrophilic PDMAEMA block sensitive to tempera-



Scheme 1.
Schematic diagram illustrating the process for preparing the amphiphilic ABCBA-type pentablock copolymer via consecutive ATRPs.

ture and pH, poly(2-dimethylaminoethyl methacrylate)-*block*-poly(2,2,2-trifluoroethyl methacrylate)-*block*-poly(ε-caprolactone)-*block*-poly(2,2,2-trifluoroethyl methacrylate)-*block*-poly(2-dimethylaminoethyl methacrylate) (PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-TFEMA-*b*-PDMAEMA), via consecutive ATRPs, as shown in Scheme 1. First, biodegradable poly(ε-caprolactone)diol (HO-PCL-OH, structure shown in Scheme 1) was used as a raw material to react with 2-bromo-propionyl bromide to obtain a bifunctional ATRP macroinitiator (Br-PCL-Br) in the presence of triethyl amine base catalyst. Secondly, the ATRP of TFEMA was carried out in the presence of the obtained bifunctional ATRP macroinitiator, and the hydrophobic triblock copolymer PTFEMA-*b*-PCL-*b*-PTFEMA was obtained. Finally, the ATRP of DMAEMA was carried out using the PTFEMA-*b*-PCL-*b*-PTFEMA triblock copolymer as the macroinitiator, and the amphiphilic ABCBA-type pentablock copolymers with a biodegradable PCL block PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA was obtained. The chemical structures of the obtained copolymers were characterized by ^{1}H NMR spectroscopy and GPC. The self-assembly behaviors of the pentablock copolymer were investigated in aqueous solution.

Experimental Part

Materials

Poly(ε-caprolactone)diol (HO-PCL-OH, $M_n = 2000$ g mol^{-1}) and 2-bromo-propionyl bromide (98%) were obtained from Aldrich Chemical Co. (Milwaukee, WI) and were used as received. The monomer, 2,2,2-trifluoroethyl methacrylate (TFEMA, 99%), was purchased from Aldrich Chemical Co. (Milwaukee, WI). It was washed with an aqueous solution of sodium hydroxide (5 wt.-%) three times, followed by deionized water until neutralization, and then dried over anhydrous magnesium sulfate, distilled under reduced pressure and stored at −18 °C. 2-(Dimethylamino)-ethyl methacrylate (DMAEMA) (chemical pure, Wuxi Xinyu Co. Ltd) was distillated before use under vacuum. *N,N,N′,N″,N″*-pentamethyldiethylenetriamine (PMDETA) (98%, Jiangsu Liyang Jiangdian Chemical Factory) was dried with 4 Å molecular sieves and distillated under reduced pressure. 2,2-Bipyridyl (bpy, 99%) was purchased from Shanghai Chemical Reagents Co. (Shanghai, China) and used as received. Copper(I) chloride (CuCl, 98+%), supplied by Shanghai Chemical Reagents Co., was dissolved in hydrochloric acid, and precipitated into a large amount of deionized water, filtered, washed with anhydrous ethanol, and finally dried under reduced pressure at room temperature. 2-Bromo-propionyl bromide (98%) was purchased from Acros and used as received. Triethylamine (analytical reagent), *N,N*-dimethyl-formamide (DMF) (analytical reagent), tetrahydrofuran (THF) (analytical reagent), 4-dimethylamino pyridine (analytical reagent) and all other chemicals were obtained from Shanghai Chemical Reagents Co. and used as received unless mentioned.

Synthesis of Br-PCL-Br Bifunctional Macroinitiator

In a 250 mL three-necked, round-bottom flask equipped with a condenser (with a drying tube attached at the top) and an argon inlet, 1.22 g of triethylamine (12 mmol), 1.962 g of 4-dimethylamine pyridine (18 mmol), and 6.21 g of 2-bromo-propionyl bromide (30 mmol) was dissolved in 100 mL of dichloromethane to give rise to a homogeneous solution. The solution was degassed by argon bubbling and cooled by an ice bath under stirring at 0 °C. Another homogeneous solution of HO-PCL-OH (10 g of HO-PCL-OH (5 mmol) was dissolved in 50 mL of dichloromethane) was added slowly to the reaction mixture under an argon atmosphere over a period of 5 h. The mixture was stirred at room temperature overnight, concentrated by rotary evaporation, and filtered. The filtrate was poured into 400 mL of an ethanol/water mixture (50/50, v/v), filtered, and the precipitate was washed with ethanol and then dried under reduced pressure at 30 °C. The product Br-PCL-Br was further purified by dissolving in THF and then reprecipitating in ethanol. The Br-PCL-Br was obtained as a white solid (8.0 g, 70.5% yield). The molecular weight (M_n) and the corresponding polydispersity index (PDI), determined from gel permeation chromatography (GPC) results, of the Br-PCL-Br macroinitiator was about 7970 g mol^{-1} and 1.30, respectively.

ATRP of TFEMA Using Br-PCL-Br as Bifunctional Macroinitiator

A typical polymerization procedure was as follows: In a 10 mL dry glass tube, Br-PCL-Br (550 mg, 0.275 mmol) was dissolved in 2 mL of DMF. CuCl (55 mg, 0.55 mmol), bpy (255 mg, 1.65 mmol) and TFEMA (3.9 mL, 27.4 mmol) were then added. The tube was thoroughly bubbled with argon for 20 min to eliminate the dissolved oxygen in the mixture, sealed, and transferred into in an oil bath held by a thermostat at 85 °C to initiate the polymerization under stirring. At the end of the reaction (50 min), the glass tube was quenched in cold water and opened, the mixture was diluted with THF, passed through a short neutral Al_2O_3 column, and precipitated into a large amount of methanol (~200 mL). The triblock copolymer, PTFEMA-*b*-PCL-*b*-PTFEMA, was dried under reduced pressure at room temperature for at least 24 h until a constant weight was obtained. The conversion of TFEMA was 80%. The M_n and PDI, determined from GPC results, of the PTFEMA-*b*-PCL-*b*-PTFEMA triblock copolymer was about 24 910 g mol^{-1} and 1.46, respectively.

ATRP of DMAEMA Using Triblock Copolymer as Bifunctional Macroinitiator

In a 10 mL dry glass tube, the triblock copolymer (PTFEMA-*b*-PCL-*b*-PTFEMA) obtained above (0.5 g, 0.03 mmol) was dissolved in 2 mL of anisole. CuCl (4 mg, 0.04 mmol), PMDETA (8.3 μL, 0.04 mmol), and DMAEMA (1.0 mL, 5.93 mmol) were added. The tube was thoroughly bubbled with argon for 20 min to eliminate the dissolved oxygen in the mixture, sealed and transferred into in an oil bath held by a thermostat at 90 °C to initiate the polymerization under stirring. At the end of the reaction (24 h), the glass tube was quenched in cold water and opened, the mixture was diluted with THF, passed through a short Al_2O_3 column, and precipitated into a large amount of petroleum ether (~200 mL). The pentablock copolymer, PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA, was dried under reduced pressure at room temperature for at least 24 h until a constant weight was obtained. The conversion of DMAEMA was 79.3%. The M_n and PDI, determined from GPC results, of the pentablock copolymer were about 59170 g mol^{-1} and 1.43, respectively.

Preparation of the Micelle Solution

The pentablock copolymer (50 mg) was first dissolved in THF (5 mL) to give a 10 mg mL^{-1} polymer solution. The polymer solution (1.0 mL) was added dropwise into 5 mL of deionized water (pH = 7.0), hydrochloric acid aqueous solution (pH = 4.0) and sodium hydroxide aqueous solution (pH = 8.5), respectively, under stirring. The micelle solution with a polymer concentration of about 1.7 mg mL^{-1} was used for the subsequent morphological studies by transmission electron microscopy (TEM).

Characterizations

The conversion of monomers was determined gravimetrically. The number-average molecular weights and molecular weight distributions of the polymers were determined using a Waters 1515 gel permeation chromatograph (GPC) equipped with a refractive index detector (Waters 2414), using HR 1, HR 2, and HR 4 (7.8 × 300 mm, 5 μm bead size) columns with a molecular weight range of 10^2 to 5×10^5 $g \cdot mol^{-1}$. THF was used as an eluent at a flow rate of $1.0\ mL \cdot min^{-1}$ and 30 °C. The GPC samples were injected using a Waters 717 plus autosampler and calibrated with poly(methyl methacrylate) standards from Waters. ^{1}H NMR spectra were recorded on an Inova 400 MHz nuclear magnetic resonance

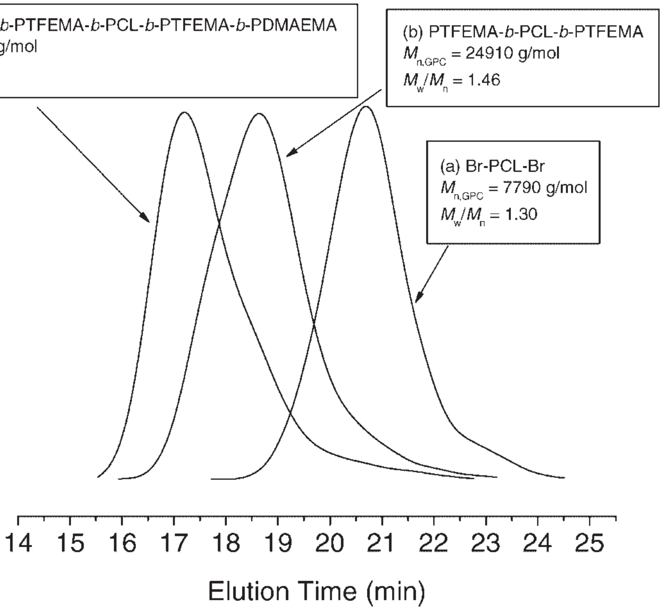


Figure 1.

GPC curves of (a) Br-PCL-Br macroinitiator prepared by the reaction between poly(ε-caprolactone) diol (HO-PCL-OH) and 2-bromo-propionyl bromide at room temperature; (b) PTFEMA-*b*-PCL-*b*-PTFEMA. obtained via ATRP of TFEMA using Br-PCL-Br as the macroinitiator, $[TFEMA]_0/[Br\text{-}PCL\text{-}Br]_0/[CuCl]_0/[bpy] = 100/1/2/6$, $[TFEMA]_0 = 4.64$ mol · L^{-1}, solvent = DMF, temperature = 85 °C, time = 50 min, conversion = 80%; and (c)PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA obtained via ATRP of DMAEMA using PTFEMA-*b*-PCL-*b*-PTFEMA as the macroinitiator, $[DMAEMA]_0/[PTFEMA\text{-}b\text{-}PCL\text{-}b\text{-}PTFEMA]_0/[CuCl]_0/[PMDETA] = 200/1/1.3/1.3$, $[DMAEMA]_0 = 2$ mol · L^{-1}, solvent = anisole, temperature = 90 °C, time = 24 h, conversion = 79.3%.

(NMR) instrument using $CDCl_3$ as the solvent and tetramethylsilane (TMS) as the internal standard at ambient temperature. Transmission electron microscopy (TEM) was recorded on a Tecnai G^2-20 TEM at a 200 kV accelerating voltage. The samples were prepared by mounting a drop of the micelle solution (~50 μL) onto the carbon-coated Cu grids and allowing the samples to dry in air.

Results and Discussion

Synthesis of Pentablock Copolymer

The synthesis of amphiphilic ABCBA-type pentablock copolymers via consecutive ATRPs is outlined in Scheme 1. The structures and average-number molecular weights of the corresponding (co)polymers for each synthetic step were studied by GPC and ^1H NMR spectroscopy. Figure 1 shows the GPC traces of the Br-PCL-Br, PTFEMA-*b*-PCL-*b*-PTFEMA triblock copolymer, and PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA pentablock copolymer. The GPC traces of the three samples show a monomodal distribution and an obvious peak shift from the macroinitiator (Br-PCl-Br) to the tri- and pentablock copolymers. It should be noted that, arising from the limited resolution of the traces, the small changes in the elution time found for the copolymers may cover a substantial percentage of imperfect polymer in various mono-, tri-, and pentablocks. Figure 2 shows the ^1H NMR spectra of these polymers. In Figure 2a, the chemical shifts at $\delta = 4.37$ ppm (*a*) and $\delta = 1.81$–1.86 ppm (*g*) can be assigned to the protons of the 2-bromo-propionyl group. The chemical shifts at $\delta = 4.04$–4.08 ppm

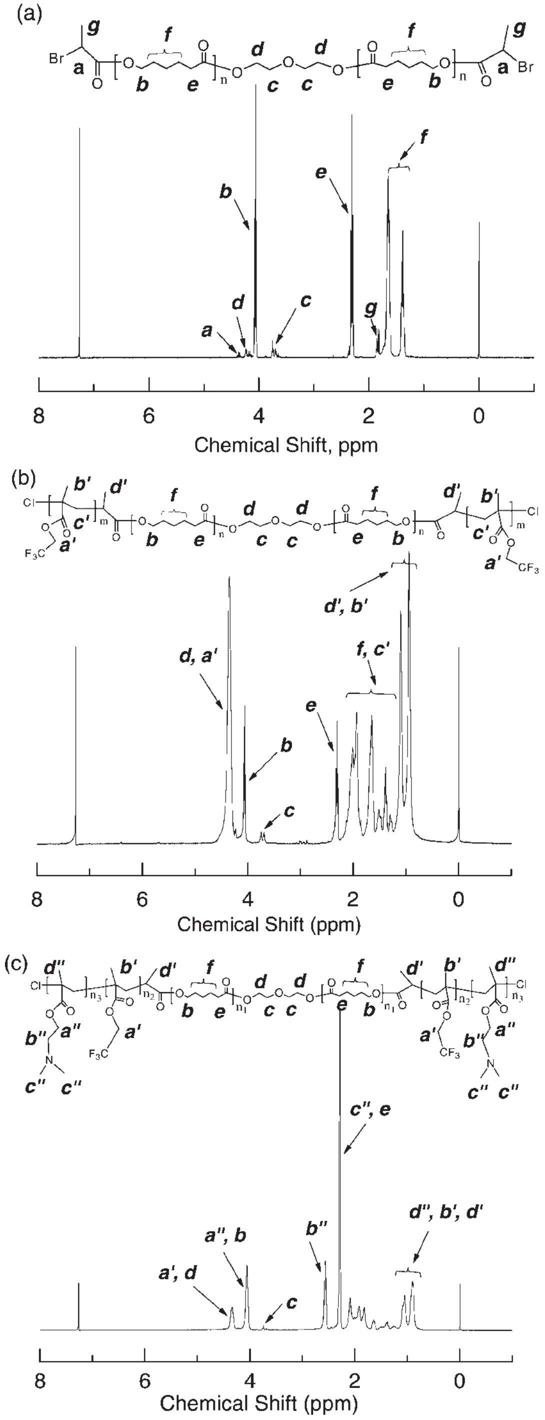


Figure 2.

^{1}H NMR spectra of (a) macroinitiator Br-PCL-Br ($M_{n,GPC} = 7790$ g/mol, PDI = 1.30), (b) triblock copolymer copolymer PTFEMA-*b*-PCL-*b*-PTFEMA ($M_{n,GPC} = 24910$ g/mol, PDI = 1.46), and (c) amphiphilic pentablock copolymer PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA ($M_{n,GPC} = 59170$ g/mol, PDI = 1.43) in $CDCl_3$.

(*b*), $\delta = 1.34$–1.73 ppm (*f*) and $\delta = 2.28$–2.33 ppm (*e*) can be assigned to the methylene protons of the caprolactone unit in the Br-PCL-Br.[34,35] The chemical shifts at $\delta = 3.68$–3.73 ppm (*c*), and $\delta = 4.15$–4.25 ppm (*d*) can be assigned to the methylene protons of the initiator moieties used for the ring-opening reaction of caprolactone in the preparation of the HO-PCL-OH polymer. These results confirm the attachment of the initiating group (2-bromo-propionyl group). In Figure 2b, the ^{1}H NMR spectrum showed new chemical shifts at 0.81–1.20 ppm (b', d'), which correspond to the methyl protons in main chain (b') of the PTFEMA block and initiating group (d') in the Br-PCL-Br macroinitiator, the peak at 4.35 ppm (a'), assigned to the methlene protons of the 2,2,2-trifluoroethyl group ($-C(O)OCHCF_3$) in the PTFEMA block,[36] along with the PCL peaks, confirm the formation of the triblock copolymer PTFEMA-*b*-PCL-*b*-PTFEMA. In Figure 2c, the ^{1}H NMR spectrum showed a new peak at 2.56 ppm (b''), which corresponds to the methylene protons next to the dimethylamino group ($-C(O)OCH_2CH_2N(CH_3)_2$) in the PDMAEMA block[37] along with the PCL and PTFEMA block peaks, confirm the formation of the pentablock copolymer PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA.

The number-average molecular weights (M_n's) and the molecular weight distributions (M_w/M_n's) of the macroinitiator and copolymers are listed in Table 1. The M_n's and M_w/M_n's of the macroinitiator and copolymers were deduced from both GPC and ^{1}H NMR spectroscopy results. Entry 1 in Table 1 shows the result for macroinitiator Br-PCL-Br. The M_n of 2000 g mol^{-1}, given by the provider (Aldrich Chemical Co.), is much less than that of 7790 g mol^{-1} deduced from GPC result, however, is in fairly good agreement with that of 2010 g mol^{-1} deduced from ^{1}H NMR spectroscopy results (ratio of the methylene protons of the caprolactone units in the Br-PCL-Br macroinitiator (*e* in Figure 2a) to the methylene protons ($-CH_2-O-CH_2-$, *c* in Figure 2a) of the initiator moieties used for the ring-opening reaction of caprolactone in the synthesis of the HO-PCL-OH polymer) for the Br-PCL-Br macroinitiator. Similarly, in entry 2 of Table 1, the theoretical M_n of 15300 g mol^{-1} is less than that of 24910 g mol^{-1} deduced from GPC result but is in fairly good agreement with that of 16400 g mol^{-1} deduced from ^{1}H NMR spectroscopy result (ratio of the methyl protons (b' in Figure 2b) of the TFEMA units in the PTFEMA block to the methylene protons (*b* in Figure 2b) of the caprolactone units in the PCL block for the triblock copolymer, PTFEMA-*b*-PCL-*b*-PTFEMA, via the ATRP process). In addition, the M_n of 42220 g mol^{-1}, deduced from ^{1}H NMR spectroscopy results (ratio of the methylene protons (b'' in Figure 2c) of the DMAEMA units in the PDMAEMA block to the methylene protons (a' in Figure 2c) of the TFEMA units in the PTFEMA block for the PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-

Table 1.
Number-Average Molecular Weights (M_n's) and Molecular Weight Distributions (M_w/M_n's) of the Synthesized Copolymers.

entry	Sample	$M_{n,GPC}^{a)}$ (g/mol)	$M_{n,NMR}^{b)}$ (g/mol)	$M_{n,th}^{c)}$ (g/mol)	$M_w/M_n^{a)}$
1	Br-PCL-Br	7790	2010	2270$^{d)}$	1.30
2	PTFEMA-*b*-PCL-*b*-PTFEMA	24910	16400	15300	1.46
3	PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA	59170	42220	41040	1.43

[#] Determined from GPC results, calibrated with PMMA standards;

b) Calculated from ^{1}H NMR results;

[a] Theoretical number-average molecular weight calculated from the molar ratio of monomer to macroinitiator and conversion of monomer except entry 1;

[b] The number-average molecular weight given by the Aldrich Chemical Co.

PTFEMA-*b*-PDMAEMA pentablock copolymer), is less than that of 59170 g mol^{-1} deduced from GPC results but is also in fairly good agreement with the theoretical value of 41040 g mol^{-1} (entry 3 in Table 1). The deviations between the theoretical values and GPC results were probably caused by the fact that the hydrodynamic volumes of the PCL, PTFEMA, and PDMAEMA blocks differ substantially from that of the linear PMMA standards. Thus, the molecular weights of the macroinitiator and tri- and pentablock copolymers deduced from ^{1}H NMR spectroscopy results were adapted. Based on M_n's estimated from the ^{1}H NMR spectroscopy

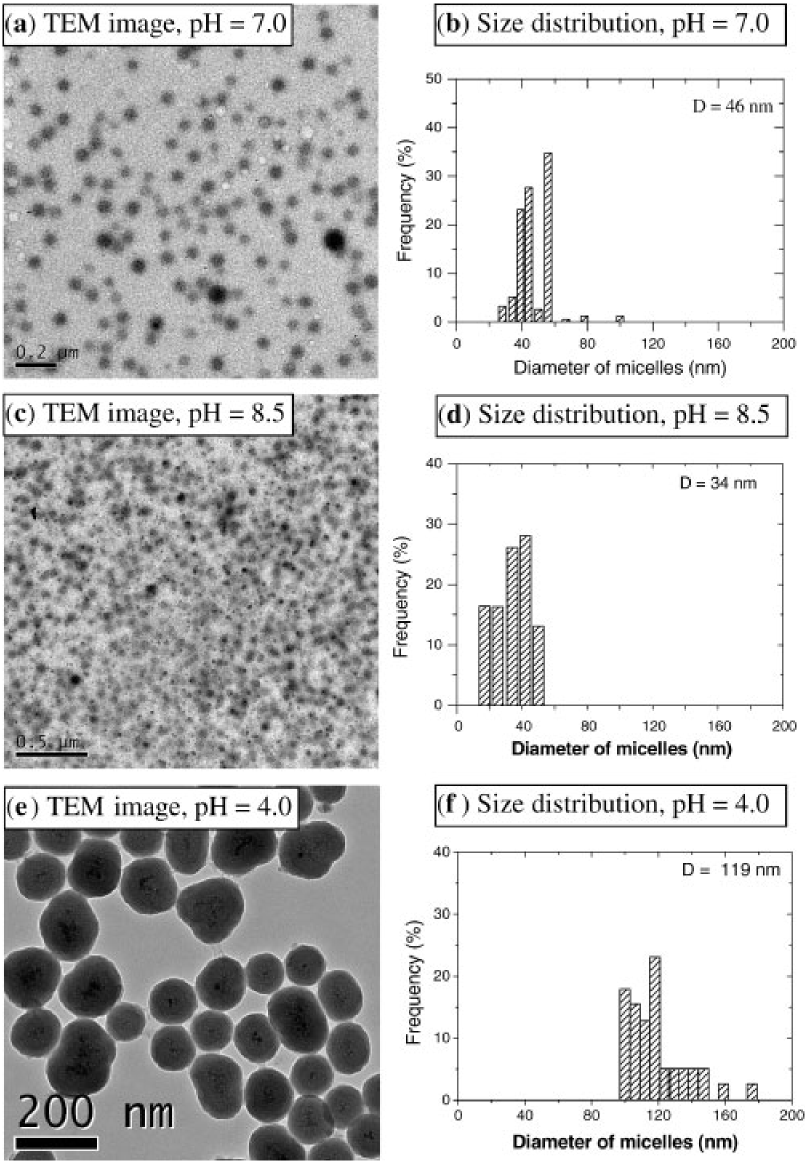


Figure 3.
TEM images (a, c and e) and corresponding size distributions (b, d and f) of the self-assembled micelles in aqueous solution at pH = 7.0, 8.5, and 4.0, respectively, from the amphiphilic pentablock copolymer PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA. $M_{n,GPC} = 59170$ g/mol, PDI = 1.43.

results, the degrees of polymerization are about 14 for the PCL block, 43 for each of the PTFEMA blocks, and about 83 for each of the PDMAEMA blocks. Thus, the Br-PCL-Br marcoinitiator is referred to as Br-PCL$_{14}$-Br, the triblock copolymer, PTFEMA-*b*-PCL-*b*-PTFEMA, as PTFEMA$_{43}$-*b*-PCL$_{14}$-*b*-PTFEMA$_{43}$, and the pentablock copolymer, PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA, as PDMAEMA$_{83}$-*b*- PTFEMA$_{43}$-*b*-PCL$_{14}$-*b*-PTFEMA$_{43}$-*b*-PDMAEMA$_{83}$. In addition, all the M_w/M_n's of the macroinitiator and block copolymers from GPC results remain less than 1.5. These results suggest that the molecular weight and composition of the amphiphilic ABCBA-type pentablock copolymer could be successfully controlled by the monomer-to-initiator feed ratios in a consecutive ATRP process.

Aggregation Behavior of Pentablock Copolymer in Aqueous Solution with Different pH

Amphiphilic block copolymers can self-assemble into micelles, vesicles and other morphologies in selective solution according to their different chemical compositions and molecular architectures.[38–42] The self-assembly morphologies of the synthesized pentablock copolymers in different pH aqueous solutions were investigated by TEM, and spherical or sphere-like micelles were prevalent in all cases. PDMAEMA blocks are water-soluble, while PCL and PTEFMA blocks are hydrophobic. Thus, the self-assembled spherical micelles probably contain a hydrophobic PCL and PTEFMA core surrounded by a hydrophilic PDMAEMA corona. When prepared at $pH = 7.0$, the micelles show a mean diameter of 46 nm (Figure 3(a)), and the micelle diameters typically range from 39 to 56 nm, as shown in Figure 3(b). When prepared at $pH = 8.5$ (ionic strength $I = 3.16 \times 10^{-6}$ mol/kg), the corresponding micelles induce a reduction of the mean diameter to 34 nm (Figure 3(c)), and the size distribution typically ranged from 17 to 50 nm, as shown in Figure 3(d). With a pK_a of 7.0–7.3, PDMAEMA can be protonated and ionized at low pH, while deprotonation above $pH = 8$ can render PDMAEMA somewhat 'hydrophobic'.[43] Therefore, at $pH = 7.0$, the neutral form of PDMAEMA is the normal case, which yields the smaller micelles; when going to basic pH, such as $pH = 8.5$, the PDMAEMA chains are fully deprotonated, which suppresses electrostatic repulsion between the positively charged ammonium groups and decreases the width of the corona, and consequently results in a decrease of the micelle diameter. When going to acidic pH ($pH = 4.0$, $I = 1 \times 10^{-4}$ mol/kg), the protonation and the more effective solvation of the PDMAEMA corona induce, consequently, a more extended corona of the micelles, which results in a rapid increase of the mean diameter of the micelles up to 119 nm (Figure 3(e)), in agreement with what is often observed for pH-sensitive micelles.[44,45]

Conclusion

Amphiphilic pentablock copolymers with a biodegradable PCL block and hydrophilic PDMAEMA blocks sensitive to pH could successfully be synthesized via two steps of consecutive ATRPs using a bifunctional ATRP macroinitiator, Br-PCL-Br. The obtained copolymer could self-assemble into nanosized micelles in deionized water. The pH of the solution had a significant effect on the size of the micelles self-assembled from the PDMAEMA-*b*-PTFEMA-*b*-PCL-*b*-PTFEMA-*b*-PDMAEMA copolymer. Decreasing the pH of the aqueous solution could increase the diameter of the micelles due to the protonation and the more effective solvation of the PDMAEMA corona in acidic solution.

Acknowledgements: The financial support of this work by the National Nature Science Foundation of China (No.20574050), the Science and Technology Development Planning of Jiangsu Province (No. BK2007702 and BK2007048), and the Nature Science Key Basic

Research of Jiangsu Province for Higher Education (No. 05KJA15008) is gratefully acknowledged.

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