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RESEARCH ARTICLE

Synthesis and characterization of radiopaque iodine-containing methacrylate-based polymers via reversible addition-fragmentation chain transfer (RAFT) polymerization

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Abstract The reversible addition-fragmentation chain transfer (RAFT) polymerization of 2-(2′-iodobenzoyl) ethyl methacrylate (2-IEMA) was performed in benzene solution using 4-cyanopentanoic acid dithiobenzoate (CPADB) as chain transfer agent to yield well-defined iodine-containing methacrylate-based polymers. It is characteristic of a controlled/living polymerization, i.e., linear increase in M_n with conversion and narrow molecular distribution. Moreover, the block copolymerization of 2-IEMA with 2-(2′,3′,4′,6′-tetra-O-acetyl-β-D-glucosyloxy)ethyl methacrylate (AcGEMA) and 2-lactobionamidoethyl methacylate (LAMA) was also carried out to give radiopaque glycopolymers by using the same methodology, respectively. The radiopacity of these polymers was evidenced by a routine medical X-ray imaging technique. TEM and DLS analytical results showed that the selected PIEMA-*b*-PLAMA diblock copolymers can self-assemble in aqueous solution into nearly spherical aggregates of 60–86 nm in diameter.

Keywords reversible addition-fragmentation chain transfer (RAFT) polymerization, iodine-containing methacrylate-based polymer, radiopacity, glycopolymer

1 Introduction

When a biomaterial is used *in vivo*, as the physician expects to noninvasively monitor its precise location in the body and locate the biomaterial after operation, it is often required that the material can be visible though X-ray fluoroscopy by the addition of contrast agents, which are usually barium salts or zirconium dioxides [1]. However, the addition of these metal salts or metal oxides usually has a detrimental effect on the mechanical properties of polymers and increases potential systemic toxicity to human body [2,3]. Recently, much interest has been focused on the synthesis of iodine-containing polymeric materials, due to their good X-ray radiopaque properties and significantly due to the fact that iodinated aromatic nuclei are the most stable opacifying agents of modern nonionic X-ray contrast media and the toxicological aspects of such systems are well documented as well [1]. These iodine-containing radiopaque polymers are generally prepared via two methods. The first one is the conventional free radical polymerization of iodine-containing (meth)acrylate monomers. For example, iodine-containing (meth)acrylates and (meth)acrylamides are routinely used to copolymerize with other acrylic monomers leading to good radiopacity of the resultant polymers [4–10]. Davy et al. [11] reported the preparation of polymeric beads based on copolymers of methyl methacrylate (MMA) monomers containing triiodobenzoate with good radiopacity and mechanical properties, which can be used in denture base acrylics or orthopedic bone cements. Koole et al. [12–14] described an iodine-containing hydrogel as a viable alternative to high-$BaSO_4$-containing cement employed for augmenting osteoporosis-induced vertebral compression fractures. Recently, two kinds of glucose- and lactose-containing methacrylate-based radiopaque glycopolymers were prepared in our group [15]. The second one is grafting iodine- containing molecules onto preformed high molecular weight polymers. For instance, Jayakrishnan et al. [16] prepared a series of radiopaque polyurethanes by grafting N-(2,6-diiodocarboxyphenyl)-3,4,5-triiodobenzamide onto the Tecoflex 80. In a similar manner, cellulose was also made radiopaque via coupling triiodobenzoic acid with hydroxyl groups of cellulose by Mottu et al. [17] for potential application as embolic agents.

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As it is well known, among the controlled/living radical polymerizations (CRPs), such as stable free radical polymerization (SFRP) [18], atom transfer radical (ATRP) polymerization [19], and reversible addition-fragmentation chain transfer (RAFT) polymerization [20], RAFT has proven to be a versatile CRP technique, suitable to a wide range of monomers, applicable in mild condition, and accessible for complex molecular architectures, such as block or gradient copolymers and star polymers [21]. However, most of the iodine-containing (meth)acrylate polymers were prepared by the conventional free radical polymerization in literatures. To this end, the synthesis of radiopaque homopolymers of 2-(2′-iodobenzoyl)ethyl methacrylate (2-IEMA) was first attempted via RAFT in this study. As the glycopolymers have attracted increasing interests for their potential applications in biochemical and biomedical fields, such as drug-delivery systems [22,23], scaffolds for tissue engineering [24,25], remedy of infectious disease [26], and treatment of HIV [27], a study on the preparation of radiopaque glycopolymers was also carried out using the RAFT homopolymer of 2-IEMA as macro-CTA to initiate the block polymerization of 2-(2′,3′,4′,6′-tetra-O-acetyl-β-D-glucosyloxy)ethyl methacrylate (AcGEMA) and 2-lactobionamidoethyl methacylate (LAMA), respectively. These iodine-containing polymeric materials were characterized by IR, ^{1}H NMR, and GPC. Their radiopacity was checked under normal clinical conditions on the X-ray detecting equipment. The micellar self-assembly behavior of the selected PIEMA-*b*-PLAMA diblock glycopolymer was also monitored in aqueous solution using TEM and DLS analyses.

2 Experimental

2.1 Materials

2-Iodobenzoic acid (95%, Fluka, Switzerland), lactobionic acid (Sigma, USA), 2-aminoethyl methacrylate (90%, Acros, Belgium), and 2-hydroxyethyl methacrylate (HEMA, 98%, Tianjin Chemical Reagent Research, China) were distilled under reduced pressure before use. Tetrahydrofuran (THF, Beijing Chemical Reagent Company, China) was distilled over sodium metal and benzophenone as a developing agent, and dichloromethane (DCM, Beijing Chemical Reagent Company, China) was dried by Calcium hydride. 2,2′-Azoisobutyronitrile (AIBN, Beijing Chemical Reagent Company, China) was purified by recrystallization in ethanol. Other chemicals were reagent grade and used as received. The monomers 2-IEMA, AcGEMA, and LAMA, as well as the RAFT CTA 4-cyanopentanoic acid dithiobenzoate (CPADB), were synthesized according to procedures introduced in Refs. [4,28–30].

2.2 Homopolymerization of 2-IEMA

In a 25-mL ampoule, 2-IEMA (1 g, 2.78 mmol) was added with 10 mL benzene solution containing AIBN (4.7 mg, 0.02 mmol) and CPADB (25.8 mg, 0.09 mmol). The reactor was then sealed, degassed with three freeze-evacuate-thaw cycle, and kept in 80°C for a predetermined period of time. After the reaction, the reaction mixture was quenched in ice water and then precipitated in hexane. It was dried *in vacuo* for 24 h to give the homopolymer PIEMA.

2.3 Block copolymerization of 2-IEMA with AcGEMA

The protocol for the RAFT block copolymerization of 2-IEMA with AcGEMA was as follows. In a 25-mL ampoule, the macro-CTA of PIEMA (0.100 g), AcGEMA (0.767 g), AIBN (0.003 g), and 10 mL anhydrous benzene were added, respectively. The reactor was then sealed, degassed with three freeze-evacuate-thaw cycle, and then heated to 80°C. At the end of the reaction for 24 h, the reaction mixture was quenched in ice water and then precipitated in hexane. The obtained glycopolymer was dried *in vacuo* for 24 h.

2.4 Block copolymerization of 2-IEMA with LAMA

The protocol for the synthesis of $PIEMA_{17}$-*b*-$PLAMA_8$ via the RAFT polymerization was as follows. In a 25-mL ampoule, the macro-CTA of PIEMA (0.100 g), LAMA (0.156 g), AIBN (0.001 g), and 10 mL anhydrous DMSO were added, respectively. The reactor was then sealed, degassed with three freeze-evacuate-thaw cycle, and then heated to 80°C. At the end of the reaction, after 24 h, the reaction mixture was quenched in ice water. The polymers were purified by dialysis against distilled water for three days and then freeze-dried to obtain white glycopolymer.

2.5 Characterization

The molecular weight and molecular weight distribution were assessed using a Waters 2410 and 2414 gel permeation chromatography (GPC) instrument using a DMF eluent at 50°C and a THF eluent at 35°C at a flow rate of 1 mL/min, respectively. Calibrations were based on polystyrene standards.

IR spectra were measured on a Shimadzu IR Prestige-21 IR spectrometer at room temperature. The spectra were obtained after accumulation of 20 scans at a resolution of 2 cm^{-1} between 500 and 4500 cm^{-1}. Powder samples were prepared by dispersing the samples in KBr and compressing the mixture to form disks.

^{1}H NMR spectra were recorded on a Bruker DMX-400 spectrometer with $CDCl_3$ or DMSO-d_6 as the solvent and TMS as the internal standard.

X-ray visibility was checked by taking an X-ray photograph of the polymer under routine hospital conditions (Shimadzu IA-9SX, rated voltage 100 V, rated power 300 W, measuring height 1 m).

Transmission electron microscopy (TEM) was performed on a Hitachi-700 microscope operating at an accelerating voltage of 100 kV. Samples were deposited onto copper grids, which were precoated with a thin supporting film of Formvar and consequently coated with carbon. The water on the sample was absorbed by the filter paper. The grids were negatively stained with 2.5% (w/w) uranyl acetate ethanol solution for 2 min.

Dynamic light scattering (DLS) studies were performed using a Brookhaven Instruments Corporation BI-200SM goniometer equipped with a BI-9000AT digital correlator using a solid-state laser (125 mW, λ = 532 nm) at a fixed scattering angle of 90°. The intensity-average hydrodynamic diameter (D_h) and polydispersity of the micelles were obtained by cumulants analysis of the experimental correlation function.

3 Results and discussion

3.1 Homopolymerization of 2-IEMA

The RAFT polymerization of the iodine-containing monomer 2-IEMA is shown in Scheme 1. A key to the controlled/living RAFT polymerization of 2-IEMA is the choice of the appropriate chain transfer agent (CTA). Dithioester compounds are typical CTA reagents for the RAFT polymerizations in which R group should be a good free radical leaving group that is capable of reinitiating polymerization, while Z species has a stabilizing effect on the intermediate radical. Herein, 4-cyanopentanoic acid dithiobenzoate (CPADB) was the choice of interest for the controlled/living polymerization of 2-IEMA because it was well documented to be an effective RAFT CTA reagent for the polymerization of various methacrylates [30–32]. Owing to commercial unavailability, CPADB is usually needed to be prepared via a multistep procedure including the synthesis of dithiobenzoic acid, oxidization to di (thiobenzoyl)-disulfide, and, finally, reaction with 4,4′-azobis(4-cyanopentanoic acid).

The homopolymerization of 2-IEMA was carried out in benzene using CPADB as RAFT CTA and AIBN as initiator. The feeding molar ratio of 2-IEMA to AIBN was controlled at 100∶1, and the feeding molar ratio of 2-IEMA to CPADB was fixed at 30∶1. The sealed reactor was put in the 80°C oil bath and quenched in ice water at the end of the polymerization. The resulting products were purified by washing with hexane. In this way, the unreacted components were eliminated. The experimental results are outlined in Table 1. The ^{1}H NMR spectra of 2-IEMA and PIEMA in $CDCl_3$ are shown in Fig. 1. Compared with the starting monomer, the absence of the double bond protons (6.2 and 5.6 ppm) and the appearance of the alkyl protons (0.8–1.2 ppm) in Fig. 1(b) indicate the occurrence of the RAFT polymerization of 2-IEMA. The other resonance peaks in PIEMA were assigned as follows. The signals of the aromatic protons of the 2-iodophenoxy group appear at 7.9–7.1 ppm and those of the side-chain CH_2 protons of the iodine-containing polymer at 4.6–4.5 ppm. The peak at 2.4 ppm is the signal from the dithiobenzoyl group at the chain end, which was employed for calculating the molecular weights of polymers according to the following equation:

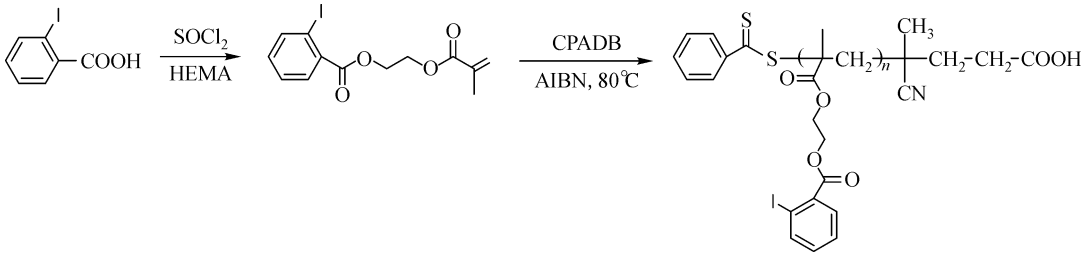
$$M_n(^1\text{H NMR}) = M_M\frac{A_{7.2}}{A_{2.4}} + M_{RAFT} \quad (1)$$

where A_x represents the integration area of the corresponding peak at chemical shift of x ppm, and M_M is the molecular weight of the monomer.

As can be seen in Table 1, the final molecular weight as determined by ^{1}H NMR is lower than the theoretical value obtained from the following formula:

$$M_n(\text{th}) = M_M\frac{[M]_0}{[RAFT]_0}p + M_{RAFT} \quad (2)$$

where M_{RAFT} is the molecular weight of the RAFT CTA agent, p is conversion ratio, and $[M]_0$ and $[RAFT]_0$ are the initial concentrations of the monomer and macroRAFT agent, respectively. The possible reason for this deviation is the loss of active thicarbonylthio functional group due to irreversible termination reactions between the various radical species [33]. On the other hand, it is maybe due to a high concentration of the chain transfer agent leading to a dramatic slowing of the overall polymerization rate [32,34].



Scheme 1 Schematic description of RAFT polymerization

Table 1 Summary of RAFT polymerization experiments

No	Time/h	CTA/%	Conv/%	$M_{n,th}$	$M_{n,NMR}$	$M_{n,GPC}$	M_w/M_n
PIEMA-4h	4	1/30	54	6089	5079[a)]	4400[c)]	1.03
PIEMA-6h	6	1/30	69	7712	5817[a)]	4400[c)]	1.03
PIEMA-8h	8	1/30	71	7970	6279[a)]	4500[c)]	1.03
PIEMA-14h	14	1/30	69	7743	6824[a)]	4500[c)]	1.04
PIEMA-24h	24	1/30	67	7521	6279[a)]	4400[c)]	1.03
$PIEMA_{17}$-b-$PAcGEMA_{50}$	24	1/50	–	29000	–	–	–
$PIEMA_{17}$-b-$PAcGEMA_{60}$	24	1/100	60	52000	33600[a)]	18796[c)]	–
$PIEMA_{17}$-b-$PAcGEMA_{108}$	24	1/200	54	98000	55680[a)]	29200[c)]	1.57
$PIEMA_{17}$-b-$PLAMA_8$	24	1/20	40	15380	9752[b)]	65700[d)]	1.09
$PIEMA_{17}$-b-$PLAMA_{20}$	24	1/30	67	20070	15380[b)]	72100[d)]	1.04
$PIEMA_{17}$-b-$PLAMA_{48}$	24	1/70	68	38830	28512[b)]	103200[d)]	1.08

a) Calculated by ^{1}H NMR with $CDCl_3$ as the solvent;
b) Calculated by ^{1}H NMR with DMSO-d_6 as the solvent;
c) Determined by GPC with THF as the eluent;
d) Determined by GPC with DMF as the eluent.

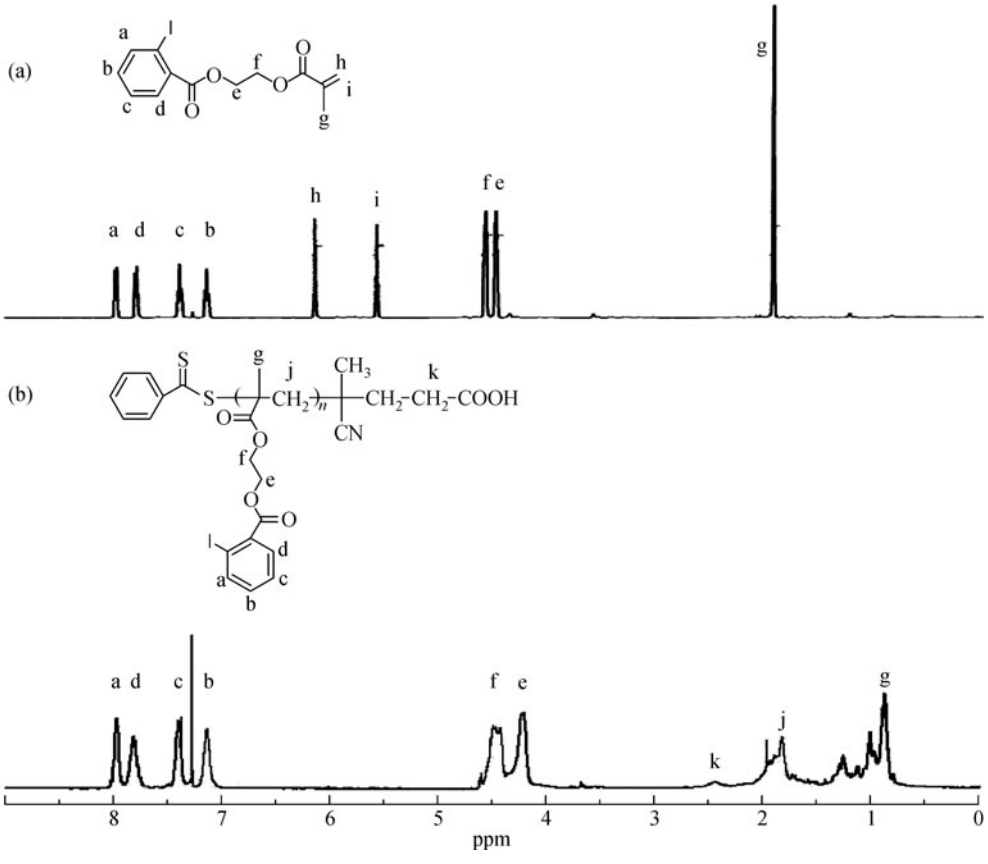


Fig. 1 ^{1}H NMR spectra of **(a)** 2-IEMA and **(b)** PIEMA

Figure 2 exhibits the IR spectra of PIEMA and 2-IEMA. In Fig. 2(b), the double bond is obvious at 1630 cm^{-1}, whereas in Fig. 2(a), no trace of the double bond is present. At the same time, the characteristic vibrations of the carbonyl appears at 1731 cm^{-1}, the aliphatic groups at 1731 cm^{-1}, and the aromatic group at 1579 cm^{-1}. The peak at 740 cm^{-1} is ascribed to the signal of C-I.

Figure 3 depicts the GPC traces of the RAFT homopolymers of 2-IEMA. The products are near-monodisperse with a narrow molecular distribution in the range

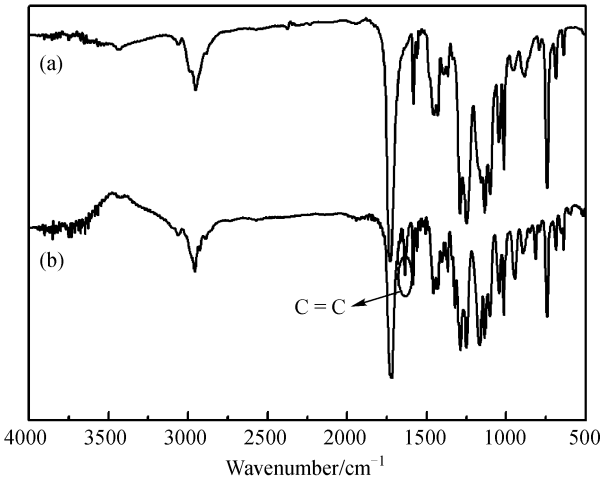


Fig. 2 IR spectra of **(a)** PIEMA and **(b)** 2-IEMA

of 1.03–1.05. It is clear that polymer peaks are shifted to lower retention time with increasing conversion. The plots of M_n and M_w/M_n versus conversion ratio are shown in Fig. 4. The number-average molecular weight increases with the conversion ratio. It is characteristic of a controlled/living polymerization. The variation in the number-average molecular weight and polydispersity as a function of the reaction conditions are summarized in Table 1. It can be seen that the final molecular weight as determined by GPC is lower than that determined by ^{1}H NMR analysis and by Eq. (2) as well. This is most likely due to the use of polystyrene as calibration standard [32,34].

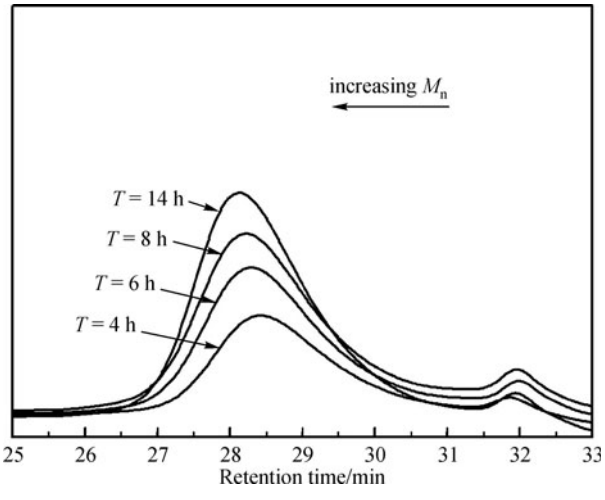


Fig. 3 GPC chromatograms for the evolution of the molecular weight with conversion for the chain extension of PIEMA

3.2 Block copolymerization of 2-IEMA with AcGEMA and LAMA

The ability to synthesize controlled architectures, such as AB diblock copolymers, is one of the features that

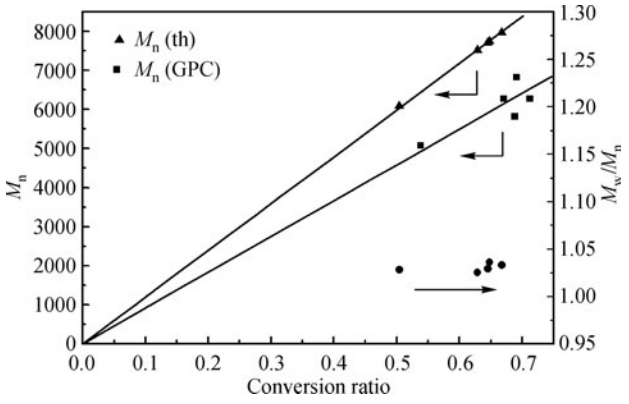
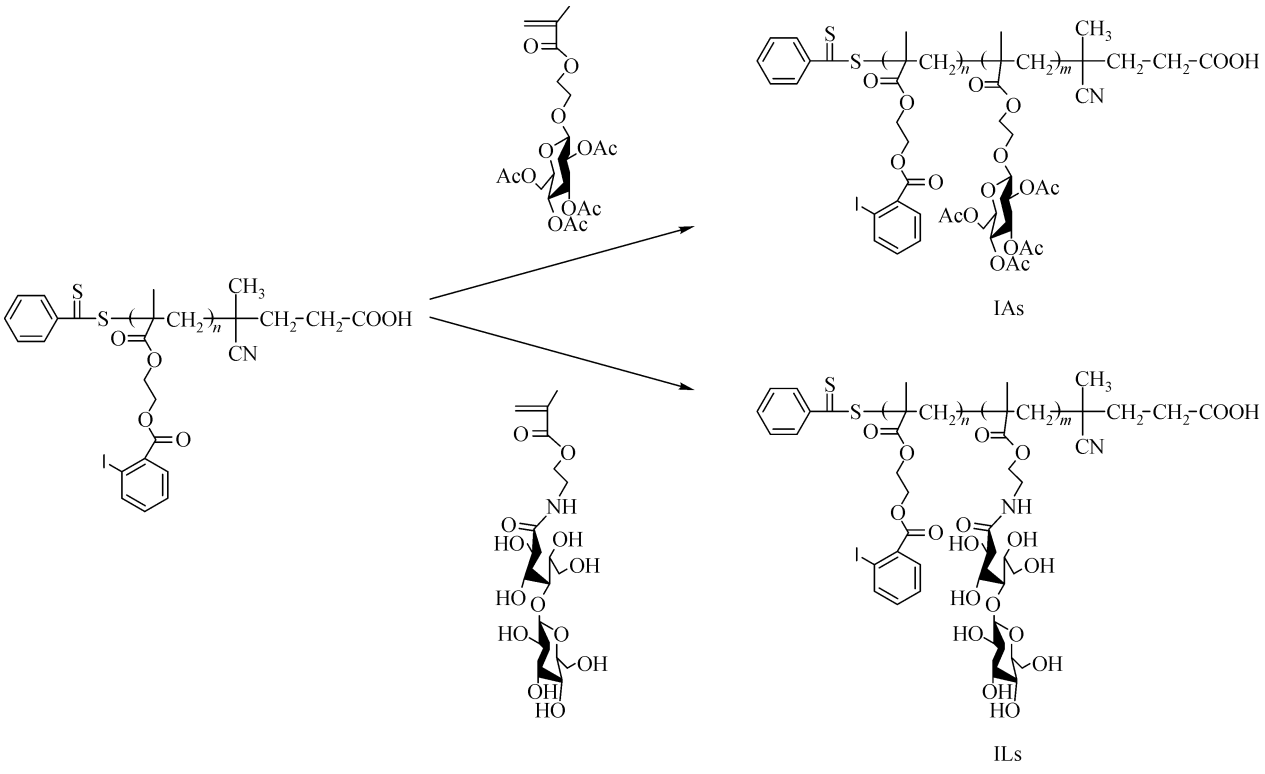


Fig. 4 Plots of M_n and M_w/M_n versus conversion for the homopolymerization of 2-IEMA

distinguish the "pseudo-living" free radical polymerization from that conventional ones. Moreover, the copolymerization of the saccharide containing (meth)acrylate moiety with radiopaque (meth)acrylate species would broaden their applications in the area of biomedicine and therapeutics as polysaccharides possess a large number of hydroxyl groups with good hydrophilic and biocompatibility, especially biorecognition. For example, Li et al. [35] reported that glucose-containing polymers can enhance specific interaction with lectin CON A. Narain and Armes [29] reported that LAMA allows molecular recognition applications that is an essential prerequisite for many biomedical and some industrial applications. As a result, further study on the block copolymerization of IEMA with AcGEMA and LAMA was carried out by using the resulting PIEMA as macro-CTA, respectively. The synthetic procedure of diblock copolymers is shown in Scheme 2. The experimental results are summarized in Table 1. As shown in Table 1, the feeding molar ratio of AcGEMA was kept higher because a bimodal distribution was seen when the molar feeding ratio of AcGEMA was relatively lower. The molecular weight distribution became monodispersed with increasing the feeding molar ratio of AcGEMA. This is most likely because the increasing concentration of the monomer is conductive to the RAFT polymerization as previously reported [36,37]. Owing to the good hydrophilicity of LAMA, its copolymerization was conducted by using DMSO as the solvent. The products were purified by dialysis against distilled water to remove the unreacted monomer LAMA, though the unreacted PIEMA cannot be eliminated completely.

Figure 5 shows the ^{1}H NMR spectra of PIEMA$_{17}$-*b*-PAcGEMA$_{60}$ and PIEMA$_{17}$-*b*-PLAMA$_8$ in $CDCl_3$ and DMSO-d_6, respectively. Compared to the ^{1}H NMR spectrum of PIEMA, the appearance of the resonance peaks at 5.2–3.8 ppm in Fig. 5(a) and 5.2–3.3 ppm in Fig. 5(b) clearly indicated that saccharide containing methacrylate moieties are successfully polymerized. The molecular weight of the diblock copolymers was calcu-



Scheme 2 Synthesis procedure for PIEMA-*b*-PAcGEMA and PIEMA-*b*-PLAMA

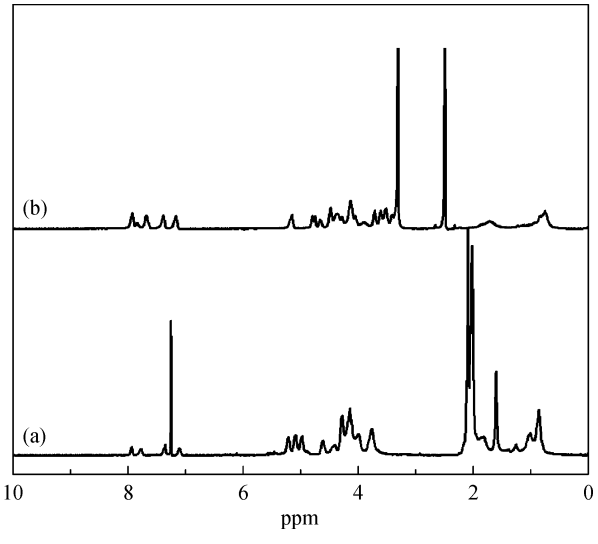


Fig. 5 ^{1}H NMR spectra of **(a)** $PIEMA_{17}$-*b*-$PAcGEMA_{60}$ and **(b)** $PIEMA_{17}$-*b*-$PLAMA_8$

lated from the ratio between the peak area of the aromatic group at 7.2 ppm and the peak area of the glycoside anomeric protons at 5.2–5.0 ppm and 5.2 ppm, respectively. The degree of polymerization (DP_n) for the diblock copolymers is still lower than their theoretical value. It is maybe due to the steric hindrance of the glycoside monomers.

The IR spectra of the diblock copolymers $PIEMA_{17}$-*b*-$PAcGEMA_{60}$ and $PIEMA_{17}$-*b*-$PLAMA_8$ are shown in Fig. 6. In Fig. 6(a), the strong absorption peak at 1726 cm^{-1} represents the ester group in sugar moiety. It is clear to see the absorption peak of hydroxyl group at 3406 cm^{-1} and the characteristic vibrations of the amide group at 1652 and 1541 cm^{-1} in the spectrum of Fig. 6(b).

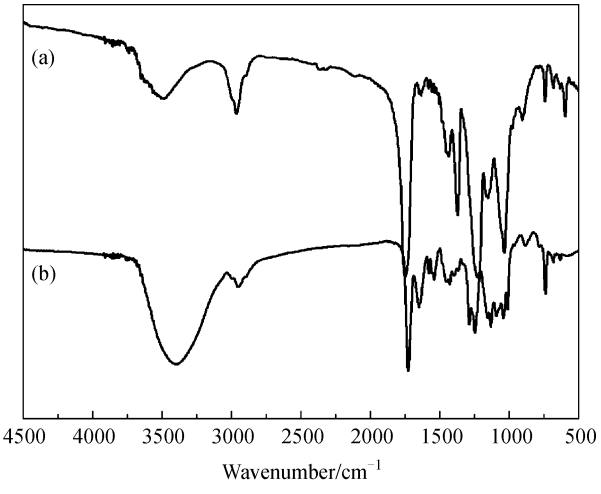


Fig. 6 IR spectra of **(a)** $PIEMA_{17}$-*b*-$PAcGEMA_{60}$ and **(b)** $PIEMA_{17}$-*b*-$PLAMA_8$

Figure 7 illustrates the evolution of molecular weight over time for the chain extension of PIEMA with AcGEMA. It clearly showed that there is a bimodal

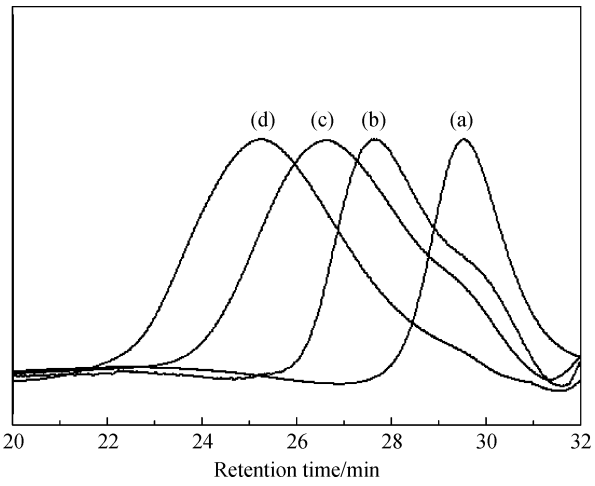


Fig. 7 GPC chromatograms for **(a)** a 2-IEMA homopolymer and its diblock copolymers with AcGEMA: **(b)** $PIEMA_{17}$-*b*-$PAcGEMA_{50}$, **(c)** $PIEMA_{17}$-*b*-$PAcGEMA_{60}$, and **(d)** $PIEMA_{17}$-*b*-$PAcGEMA_{108}$ (THF as eluent)

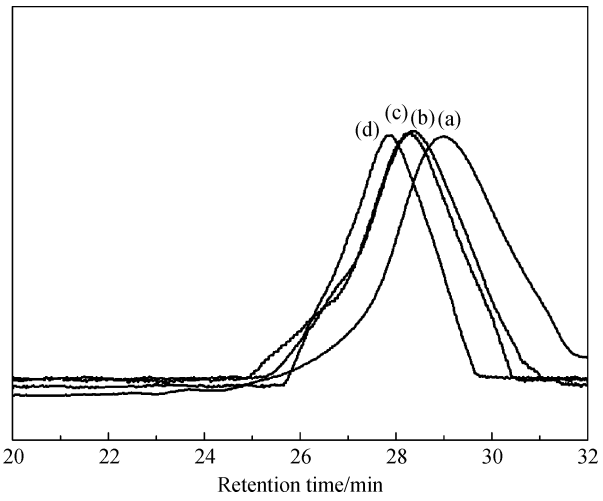


Fig. 8 GPC chromatograms for **(a)** a 2-IEMA homopolymer and its diblock copolymers with the LAMA: **(b)** $PIEMA_{17}$-*b*-$PLAMA_8$, **(c)** $PIEMA_{17}$-*b*-$PLAMA_{20}$, and **(d)** $PIEMA_{17}$-*b*-$PLAMA_{48}$ (DMF + Li as eluent)

distribution in the GPC trace of $PIEMA_{17}$-*b*-$PAcGEMA_{50}$. However, when the feeding molar ratio of AcGEMA increases, the GPC trace becomes close to mono-dispersing. In addition, the polymer peaks are shifted to lower retention time with the increase in AcGEMA, and at the same time, the molecular weight distribution is broadened, in agreement with the RAFT polymerization principle. Figure 8 depicts the GPC traces of PIEMA-*b*-PLAMA using DMF as the eluent. The molecular weight of PIEMA-*b*-PLAMA also increases with the content of LAMA. In addition, the molecular weight distribution nearly mono-disperses with a narrow molecular distribution in the range of 1.04–1.09. However, the molecular weight of these diblock copolymers was overestimated. This is maybe because GPC was carried out using DMF as eluent with polystyrene as standards. Beers et al. noticed that using the GPC protocol of MMA-HEMA diblock copolymer could overestimate the true molecular weight [38]. As a result, this discrepancy was due to calibration errors in the GPC analysis, since polystyrene standards are unlikely to be reliable for the analysis of HEMA homopolymers.

3.3 X-ray imaging of polymers

Figure 9 shows the X-ray absorption image of the homopolymer PIEMA and glycopolymers $PIEMA_{17}$-*b*-$PAcGEMA_{60}$ and $PIEMA_{17}$-*b*-$PLAMA_8$. It can be concluded that both homopolymer and glycopolymers have adequate X-ray visibility. Compared with aluminum and PMMA, an iodine-containing polymer disk thick in 0.50 mm offers the better X-ray opacity than an aluminum plate thick in 1.52 mm. It can be seen here that the radiopacities of $PIEMA_{17}$-*b*-$PAcGEMA_{60}$ thick in 0.75 mm and $PIEMA_{17}$-*b*-$PLAMA_8$ thick in 0.52 mm are equal to an aluminum plate thick in 0.76 mm. It is evident that $PIEMA_{17}$-*b*-$PLAMA_8$ has better radiopacity than that of $PIEMA_{17}$-*b*- $PAcGEMA_{60}$ due to its higher content of iodine.

3.4 Self-assembly/aggregation studies

It is well-documented that amphiphilic diblock glycopolymers could form micelle-like spheres in aqueous medium [39,40]. $PIEMA_{17}$-*b*-$PLAMA_8$ and $PIEMA_{17}$-*b*-$PLAMA_{20}$ were selected to highlight the self-assembly behavior of the resulting radiopaque glycopolymers. They were dissolved in DMF to give a solution with a concentration of 10 mg/mL. Water was then added slowly to the solution to induce the aggregation of the PIEMA block. The morphology of both selected copolymers in aqueous solution was examined by TEM. Figure 10 demonstrates the formation of nearly spherical nanoparticles from these glycopolymers. DLS was also performed to estimate their number-average particle diameters. As shown in Fig. 11(a), particle diameters of around 60 nm were observed in 0.0025 mg/mL solutions of $PIEMA_{17}$-*b*-$PLAMA_8$. Similarly, $PIEMA_{17}$-*b*-$PLAMA_{20}$ (0.0025 mg/mL) produced uniform spheres with particle diameters of about 86 nm in Fig. 11(b). It demonstrated that this kind of diblock radiopaque glycopolymers may be useful for drug delivery applications with X-ray contrast character.

4 Conclusions

The RAFT polymerization using CPADB as the chain transfer agent proved to be a viable method to synthesize

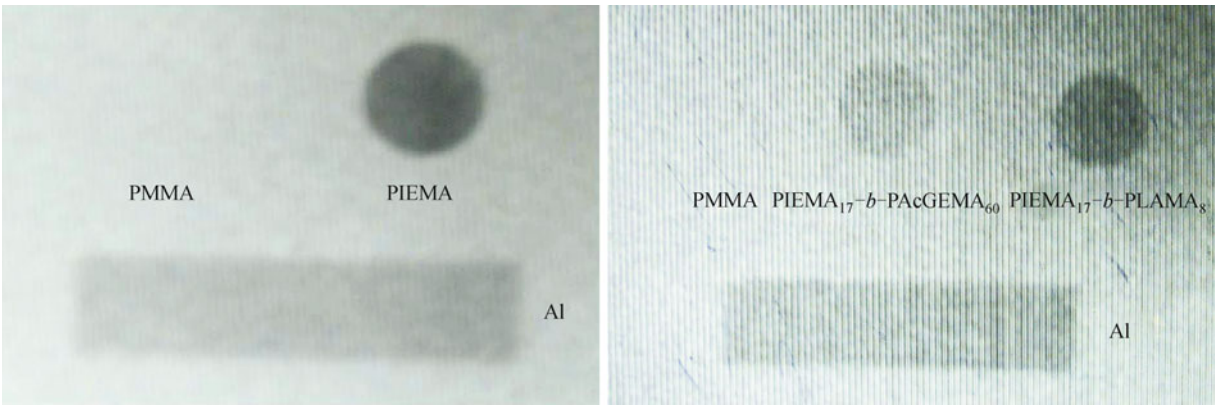


Fig. 9 X-ray photographs of PMMA, aluminum, homopolymer PIEMA, copolymers $PIEMA_{17}$-*b*-$PAcGEMA_{60}$, and $PIEMA_{17}$-*b*-$PLAMA_8$

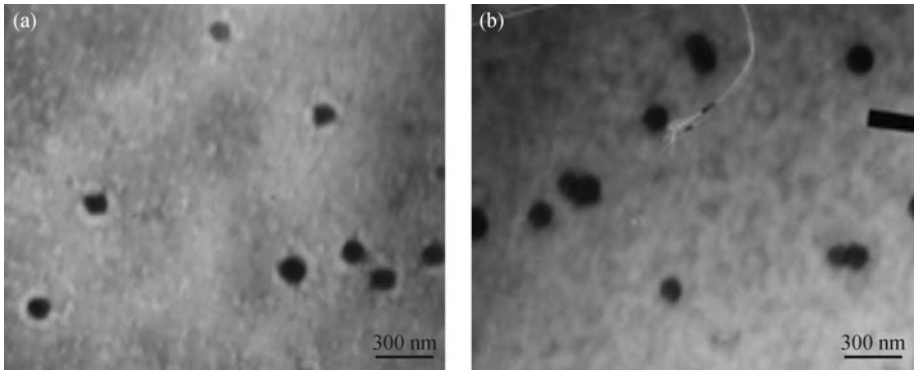


Fig. 10 TEM microphotographs of nearly spherical aggregates from diblock glycopolymer in water: **(a)** $PIEMA_{17}$-*b*-$PLAMA_8$; **(b)** $PIEMA_{17}$-*b*-$PLAMA_{20}$

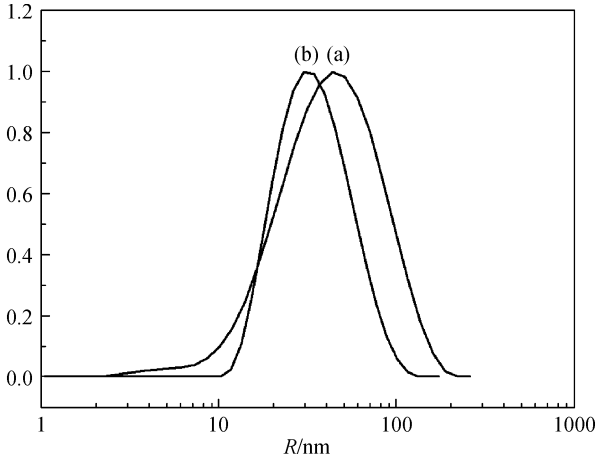


Fig. 11 Hydrodynamic diameters of **(a)** $PIEMA_{17}$-*b*-$PLAMA_8$ and **(b)** $PIEMA_{17}$-*b*-$PLAMA_{20}$ measured by DLS at 0.0025 mg/mL

iodine-containing 2-IEMA radiopaque polymers. Its homopolymerization displays the characteristics of a controlled/living polymerization. Its diblock copolymers with saccharide methacrylate moieties can also be prepared by the resulting dithioester end-capped PIEMA as the macro-CTA agent. These iodine-containing polymers have adequate X-ray visibility. The selected diblock glycopolymers $PIEMA_{17}$-*b*-$PLAMA_8$ and $PIEMA_{17}$-*b*-$PLAMA_{20}$ can self-assemble in aqueous solution into nearly spherical aggregates. It provides a route to synthesize radiopaque glycopolymers, showing potential to be used for biomedicine and therapeutics, e.g., drug-delivery systems, blood pool, endovascular stents, etc.

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