Synthesis of star-shaped PLLA with Sn catalyst and multifunctional initiators

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Abstract: The purpose of this study was to synthesize star-shaped PLLA with Tin catalyst to overcome the drawbacks of PLLA for a drug delivery system. Star shaped PLLA was synthesized by two polymerization methods, bulk polymerization and solution polymerization, using amine initiators having various OH groups. The thermal properties and crystallinity of the synthesized polymer were confirmed by DSC and XRD. It has been confirmed that as the number of branches was increased, the T_m was lowered and the crystallinity was lowered. It was confirmed that the thermal properties and crystallinity of the polymers can be controlled by synthesizing PLLA with various star shape structures. Star shaped PLLA with controlled properties is expected to have controlled release kinetics if applied as a drug delivery carrier.

Keywords: synthesis, PLLA, star-shaped.

1. Introduction

Drug delivery technology using biodegradable polymer particles is attracting attention for effective drug delivery[1]. Poly(L-lactide) (PLLA) is a biodegradable and biocompatible polymer that is used in various medical applications as well as drug delivery carriers[2-3]. However, there is an obstacle in that the decomposition rate is slow due to high crystallinity and low hydrophilicity, and the release rate is slow due to difficulty in penetration of water in the drug release system[4-5]. In order to overcome the disadvantages of PLLA, this study synthesized star-shaped PLLA based on Sn catalyst, which is a branched polymer, and confirmed the thermal properties and crystallinity of the synthesized polymers through DSC and XRD.

2. Experimental

All reactions were performed in a nitrogen atmosphere using glove box and schlenk techniques. N-butyldiethanolamine (NBDA), triethanolamine (TEA) and N, N, N ', N'-tetrakis(2-hydroxyethyl) ethylenediamine (TEED) were used as initiators.

(1) Bulk polymerization of star-shaped poly(L-lactide)

A mixture of 2 g (14 mmol) of L-lactide, certain amount of $Sn(Oct)_2$ and initiator was stirred in an oil bath at 130 ℃ for 15 min. After the reaction, the polymer was dissolved in MC and precipitated in methanol. The resulting polymer was separated from the solvent by vacuum filtration, dried at room temperature for one day and vacuum dried for 1 h.

(2) Solution polymerization of star-shaped poly(L-lactide)

A mixture of 1 g (6.9 mmol) of L-lactide, 5 mL of toluene, certain amount of $Sn(Oct)_2$ and initiator was stirred in an oil bath at 105 ℃ for 3 h. After the reaction, the polymer was precipitated and stirred in methanol and then separated from the solvent by vacuum filtration. The resulting polymer was vacuum dried for 1 h after drying at room temperature for one day.

3. Results and discussion

The synthesized polymer was represented by xLPLLA and xSPLLA depending on the type of initiator. Where x is the number of branches of the polymer, L is the linear shape, and S is the star shape. The analytical results of the synthesized polymer are shown in Table 1. T_m decreased as the number of branches of polymer increased. ΔH_m and X_c were directly related to the crystallinity of the polymer and decreased as the number of polymer branches increased. It was confirmed that the thermal properties and crystallinity can be controlled by controlling the number of polymer branches synthesized using various initiators. XRD analysis was performed for additional crystallinity analysis (Figure 1). All synthesized star shaped PLLA have three characteristic crystalline peaks at 2θ = 8.3 °, 9.51 ° and 11.12 °. It was confirmed that the crystalline peak intensities of PLLA decreased as the number of branches of polymer increased.

Table 1. Results on polymerization of L-lactide with various initiator.

Polymer	Initiator	[LA]/[Cat.]	Conversion (%)	M_n[c] (g/mol)	T_g[d] (°C)	T_m[d] (°C)	ΔH_m[d] (J/g)	X_c[e] (%)
2LPLLA[a]	NBDA	200	84.0	8700	-	154.1	50.95	54.4
3SPLLA[a]	TEA		76.9	8900	45.0	130.3	32.53	34.8
4SPLLA[a]	TEED		72.2	9100	31.9	-	-	-
2LPLLA[b]	NBDA	200	85.3	7800	42.3	146.6	43.6	46.6
3SPLLA[b]	TEA		86.1	9500	46.7	145.9	40.7	43.5
4SPLLA[b]	TEED		75.4	9800	46.4	145.3	37.0	39.5

[a] Bulk polymerization condition: L-lactide = 2 g (14 mmol), temperature = 130 ℃, time = 15 min, [LA]/[I]=50.

[b] Solution polymerization condition: L-lactide = 1 g (6.9 mmol), [LA]/[I]=200, toluene=5 ml, temperature=105 ℃, time=3 h.

[c] determined by GPC analysis with polystyrene standard.

[d] determined by DSC analysis.

[e] Xc = ΔHm/ΔHmo*100; ΔHmo = 93.6 J/g.

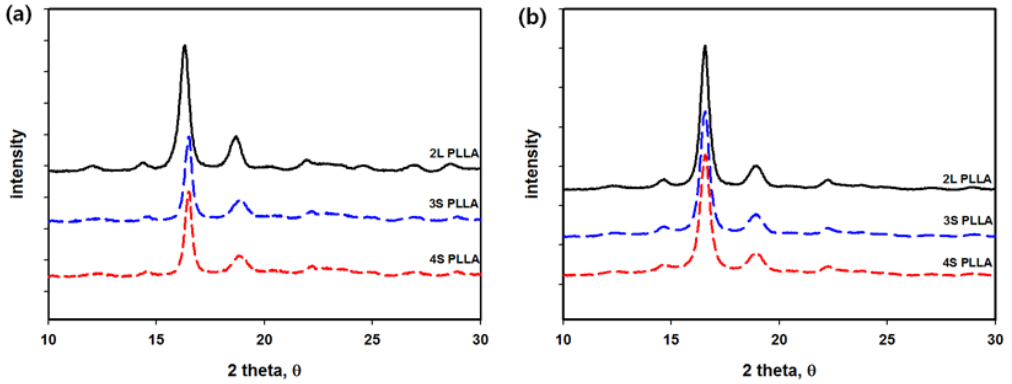

Figure 1. XRD patterns of PLLAs with different numbers of arms; (a) bulk polymerization ([LA]/[Cat.]=200, [LA]/[I]=50), (b) solution polymerization([LA]/[Cat.]=200, [LA]/[I]=200).

4. Conclusions

In this study, star-shaped PLLA, a branched polymer, was synthesized with Sn catalyst and multifunctional initiators to complement the high crystallinity of PLLA. As the number of branches of polymer increased, the melting point of star - shaped PLLA decreased and crystallinity decreased. It was confirmed that the thermal properties and crystallinity of the polymers can be controlled by synthesizing PLLA with various star shape structures. The thermal properties and crystallinity of polymers used as drug delivery systems are important factors in determining drug release rate. Therefore, star-shaped PLLA with controlled properties is expected to be used in various fields of medicine as well as in drug delivery systems.

References

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