

Supporting Information for

Understanding the CDSA of poly(lactide) containing triblock copolymers

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Synthesis Procedures

RAFT agent 2-(dodecylthiocarbonothioylthio)-2-methylpropionic acid (DDMAT).

Although CTAs with different structure might affect the assembly morphology according to previous work,¹ the CTAs we utilized in our diblock and triblock copolymer system will not affect the structure because the Z group of both CTAs are exactly the same (dodecyl). We choose different CTAs for the benefits of the synthesis. The synthesis of DDMAT was based on a previously reported literature procedure.² Acetone (500 mL) was added to a mixture of dodecanethiol (13.33 g, 65.87 mmol), potassium phosphate (14.87 g, 70.06 mmol) and carbon disulphide (13.68 g, 179.64 mmol) and stirred overnight. Bromoisobutyric acid (10 g, 59.88 mmol) was added, and the yellow solution stirred for 72 hours. Acetone was removed *in vacuo*, and the resultant yellow solid dissolved in DCM. The organic layer was washed with hydrochloric acid (1 M, 100 mL × 2), deionised water (100 mL × 3) and brine (100 mL × 2). The yellow solution was dried over magnesium sulphate, filtered and concentrated *in vacuo* before purification by washing with cold hexane. The yellow solid (14.72 g, 62%) was filtered off and then dried under vacuum. ¹H NMR (CDCl₃): δ (ppm) 11.30 (br s, 1H, COOH), 3.29 (t, 2H, SCH₂, ³J_{H-H} = 7.4 Hz), 1.73 (s, 6H, (CH₃)₂), 1.26-1.71 (m, 20H, CH₂(CH₂)₁₀) 0.88 (t, 3H, CH₂CH₃, ³J_{H-H} = 6.7 Hz). ¹³C NMR (CDCl₃): δ (ppm) 177.6, 54.5, 36.1, 30.9, 28.6, 28.5, 28.4, 28.3, 28.1, 28.0, 26.8, 24.1, 13.1.

Atomic Force Microscopy (AFM). Samples for AFM analysis were prepared by drop casting 7 μL of polymer in methanol (0.25 mg/mL) onto silicon wafer followed by drying with compressed air. Imaging and analysis were performed on an Asylum Research MFP3D-SA atomic force microscope in alternate contact (tapping) mode

Static light scattering (SLS) measurements were conducted with an ALV-CGS3 compact goniometer, with incident laser wavelength of λ = 632 nm. The sample was maintained at a constant temperature, 25°C. The average scattering intensity at the detector was calculated from 5 repeat measurements, each for twenty seconds, recorded over the angular range 30° to 150° at 10° intervals. Using the proprietary software supplied by ALV, the Raleigh ratio was normalised by the factor Kc, where K is a function of the optical parameters of the solvent and c is the sample concentration.

Table S1. Characterization data of PLLA and CTA-PLLA-CTA. The M_n determined by SEC is on the basis of polymer hydrodynamic volume of the polymer, the deviation mainly caused by the difference of the polymer PLLA from standard calibration polymer PMMA.

Polymers	$M_{n,NMR}^a$ (kDa)	$M_{n,SEC}^b$ (kDa)	\mathcal{D}_M^b
PLLA ₂₅	3.6	8.5	1.03
PLLA ₃₂	4.6	9.8	1.04
PLLA ₅₀	7.2	14.2	1.02
PLLA ₆₈	9.8	17.6	1.05
CTA-PLLA ₂₅ -CTA	-	9.1	1.05
CTA-PLLA ₃₂ -CTA	-	10.1	1.03
CTA-PLLA ₅₀ -CTA	-	14.2	1.09
CTA-PLLA ₆₈ -CTA	-	17.8	1.07

^a Measured by ¹H NMR spectroscopy in CDCl₃. ^b Measured by DMF SEC using RI detector.

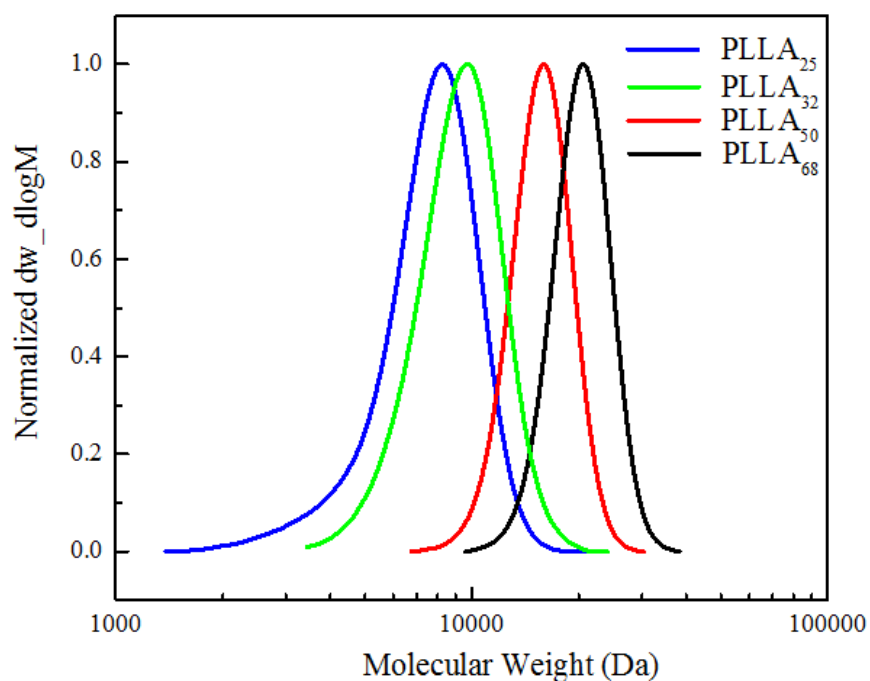


Figure S1. An overlay of SEC traces of homopolymer PLLA₂₅, PLLA₃₂, PLLA₅₀, PLLA₆₈ (DMF with 5 mM NH₄BF₄).

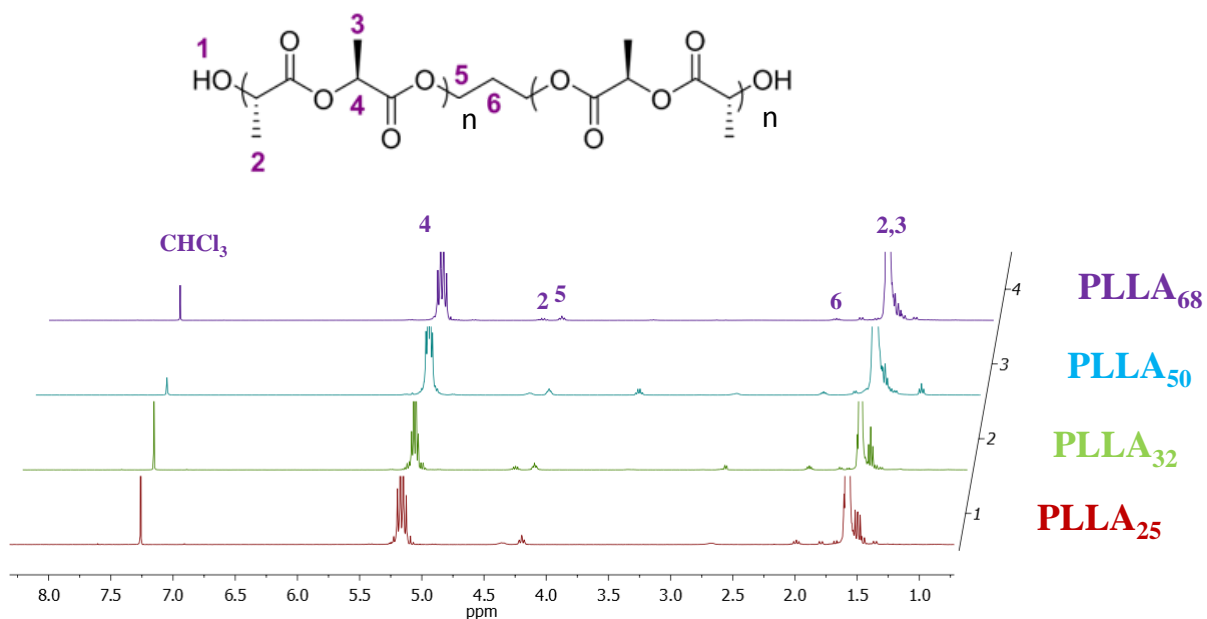


Figure S3. ^1H NMR spectra (400MHz, CDCl_3) of various PLLA homopolymers PLLA₂₅, PLLA₃₂, PLLA₅₀, PLLA₆₈.

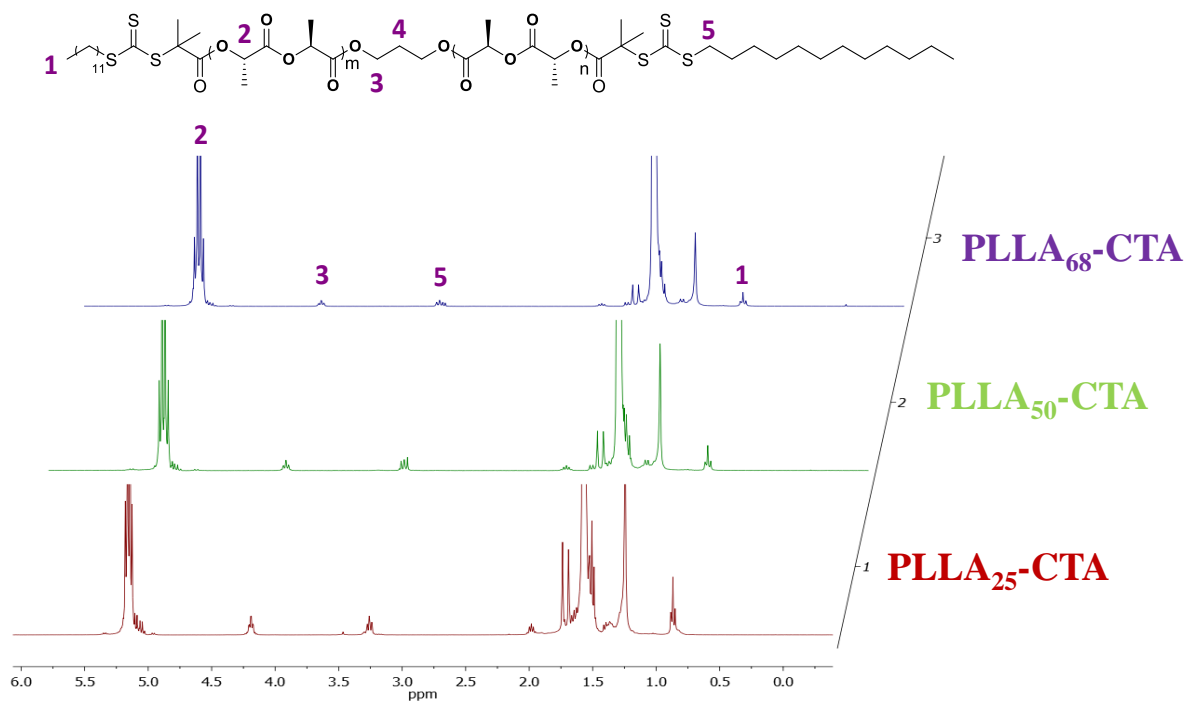


Figure S4. ^1H NMR spectra of CTA-PLLA-CTA macro-initiator PLLA₂₅-CTA, PLLA₅₀-CTA, PLLA₆₈-CTA.

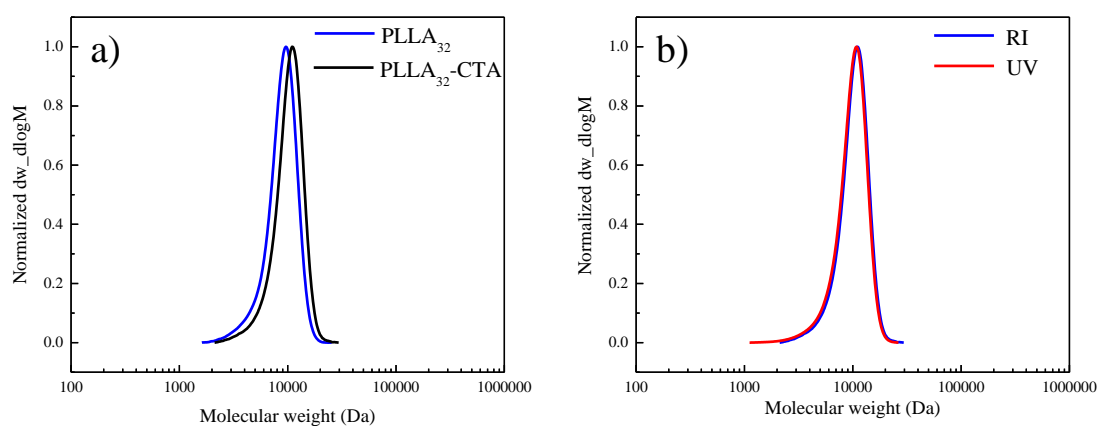


Figure S5. a) An overlay of SEC RI traces of homopolymers PLLA₃₂ and macro-CTA CTA-PLLA₃₂-CTA (DMF with 5 mM NH₄BF₄). b) An overlay of SEC RI and UV traces of CTA-PLLA₃₂-CTA macro-initiator (DMF with 5 mM NH₄BF₄).

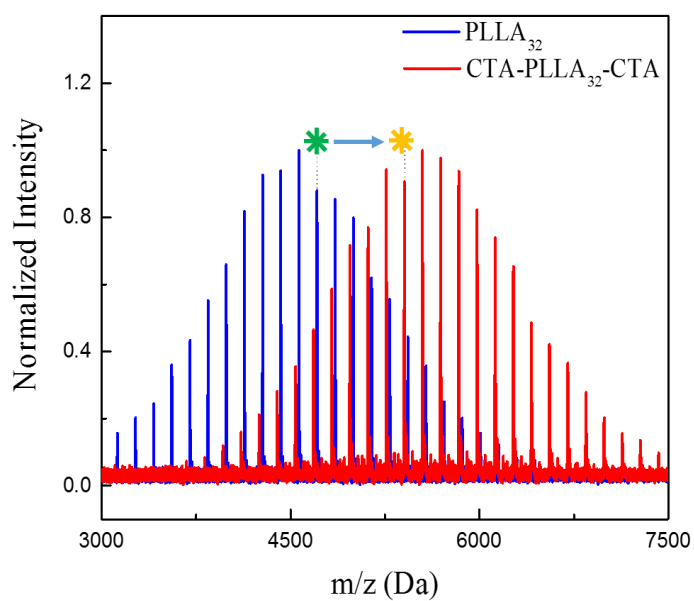


Figure S6. An overlay of MALDI-ToF mass spectra of polymer PLLA₃₂ and CTA-PLLA₃₂-CTA.

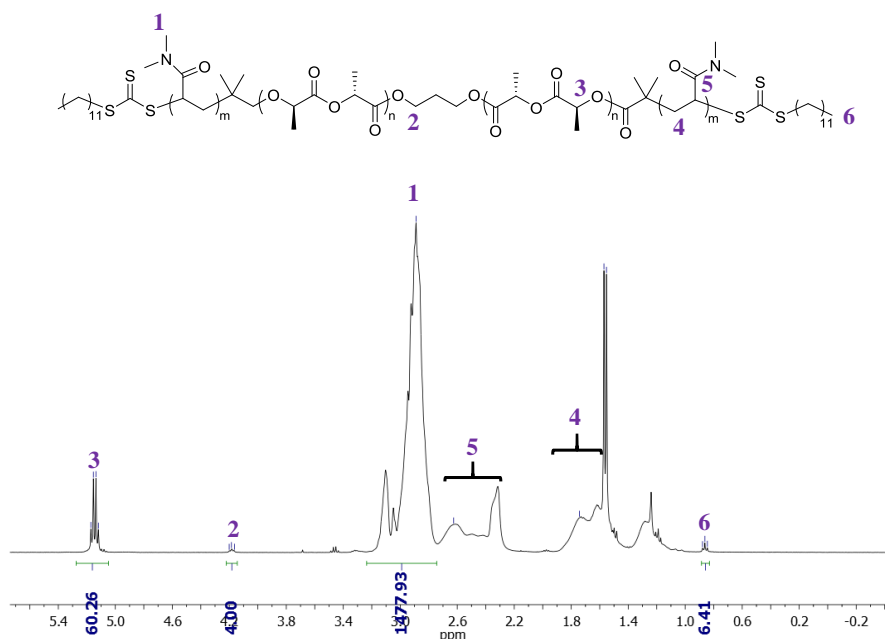


Figure S7. ^1H NMR spectrum of PDMA-*b*-PLLA-*b*-PDMA triblock copolymer **T7** (400 MHz, CDCl_3).

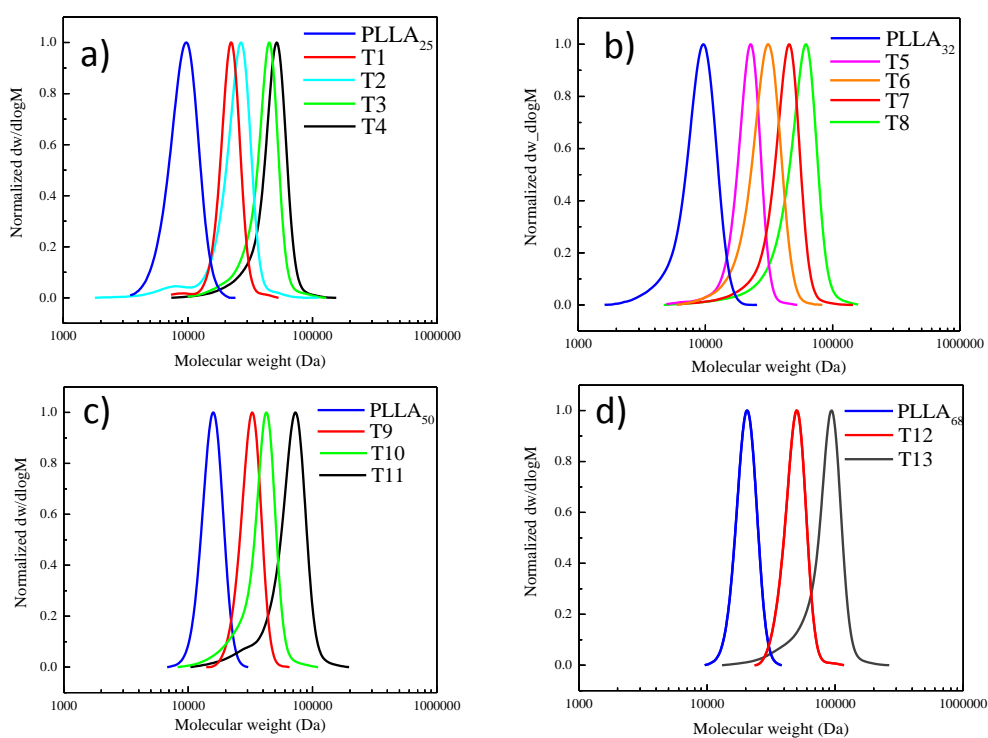


Figure S8. An overlay of SEC traces of polymers (DMF with 5 mM NH_4BF_4). a) Macro-initiator **PLLA₂₅** and PDMA-*b*-PLLA-*b*-PDMA triblock copolymers **T1-T4**. b) Macro-initiator **PLLA₃₂** and PDMA-*b*-PLLA-*b*-PDMA triblock copolymers **T5-T8**. c) Macro-initiator **PLLA₅₀** and PDMA-*b*-PLLA-*b*-PDMA triblock copolymers **T9-T11**. d) Macro-initiator **PLLA₆₈** and PDMA-*b*-PLLA-*b*-PDMA triblock copolymers **T12, T13**.

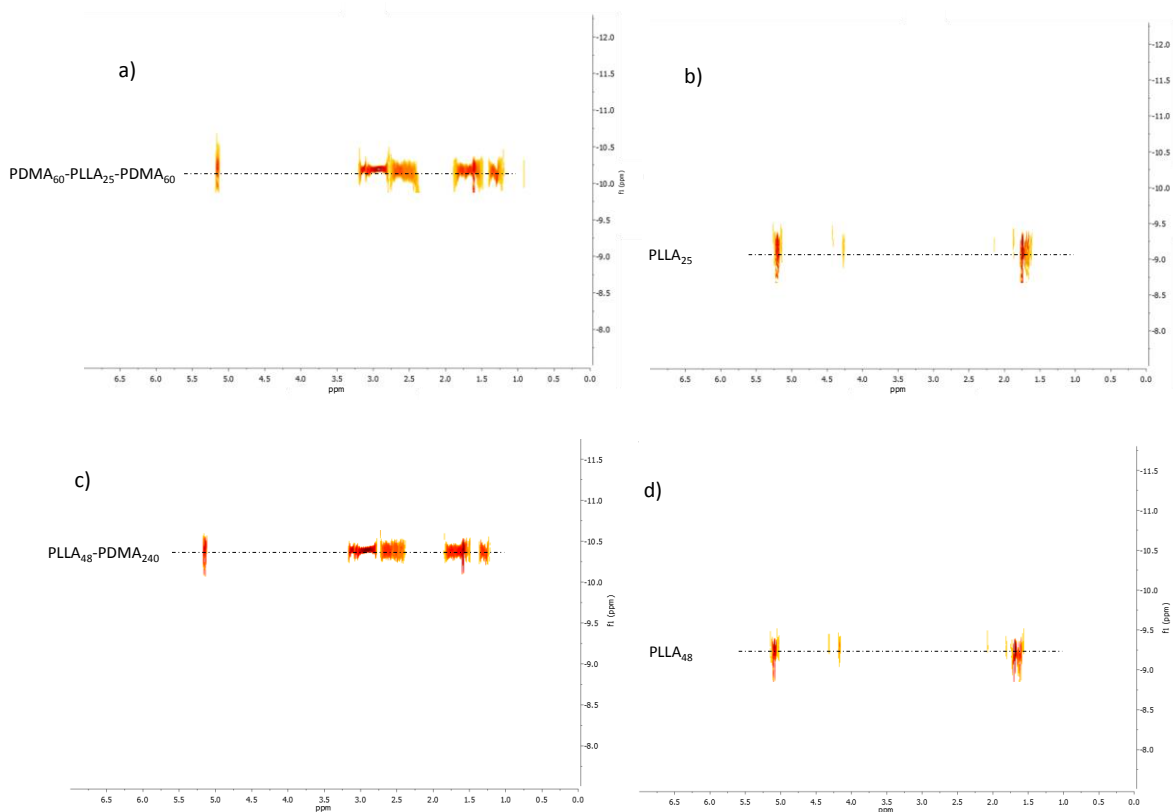


Figure S9. ¹H-DOSY NMR spectra (500 MHz) of (a) triblock copolymer **T2**, PDMA₆₀-PLLA₂₅-PDMA₆₀, (c) diblock copolymer **D4**, PLLA₄₈-PDMA₂₄₀, (b) homopolymer PLLA₂₅ and (d) PLLA₄₈ in CDCl₃ at 298 K. The results confirm there is no PLLA homopolymer present in either the diblock or triblock samples.

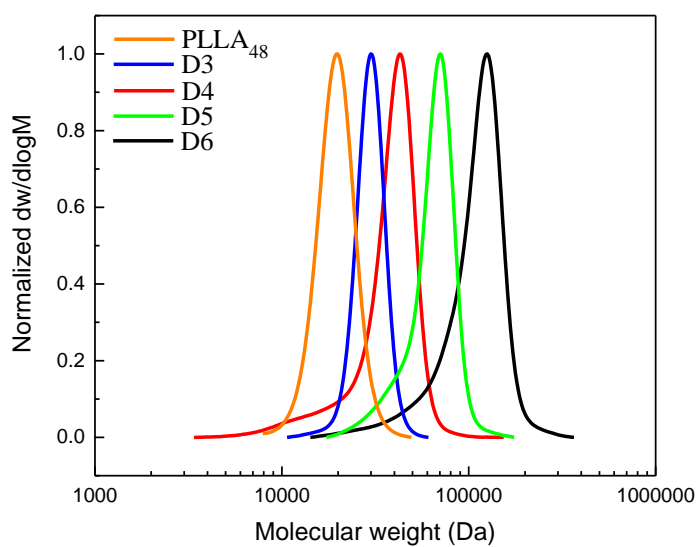


Figure S10. An overlay of SEC traces of polymers: homopolymer PLLA₄₈ and PLLA-*b*-PDMA diblock copolymers **D3-D6** (DMF with 5 mM NH₄BF₄).

a)	Triblock copolymers	D_h^* / nm	PD
	PDMA ₁₂₂ - <i>b</i> -PLLA ₃₂ - <i>b</i> -PDMA ₁₂₂ , T7	867.3	0.24
	PDMA ₄₅ - <i>b</i> -PLLA ₃₂ - <i>b</i> -PDMA ₄₅ , T5	270.3	0.20
	PDMA ₂₂₅ - <i>b</i> -PLLA ₅₀ - <i>b</i> -PDMA ₂₂₅ , T10	221.8	0.21
	PDMA ₇₅ - <i>b</i> -PLLA ₅₀ - <i>b</i> -PDMA ₇₅ , T9	226.5	0.23
	PDMA ₃₁₅ - <i>b</i> -PLLA ₆₈ - <i>b</i> -PDMA ₃₁₅ , T13	238.3	0.21
	PDMA ₁₁₅ - <i>b</i> -PLLA ₆₈ - <i>b</i> -PDMA ₁₁₅ , T12	250.4	0.24

* D_h and PD by DLS in methanol.

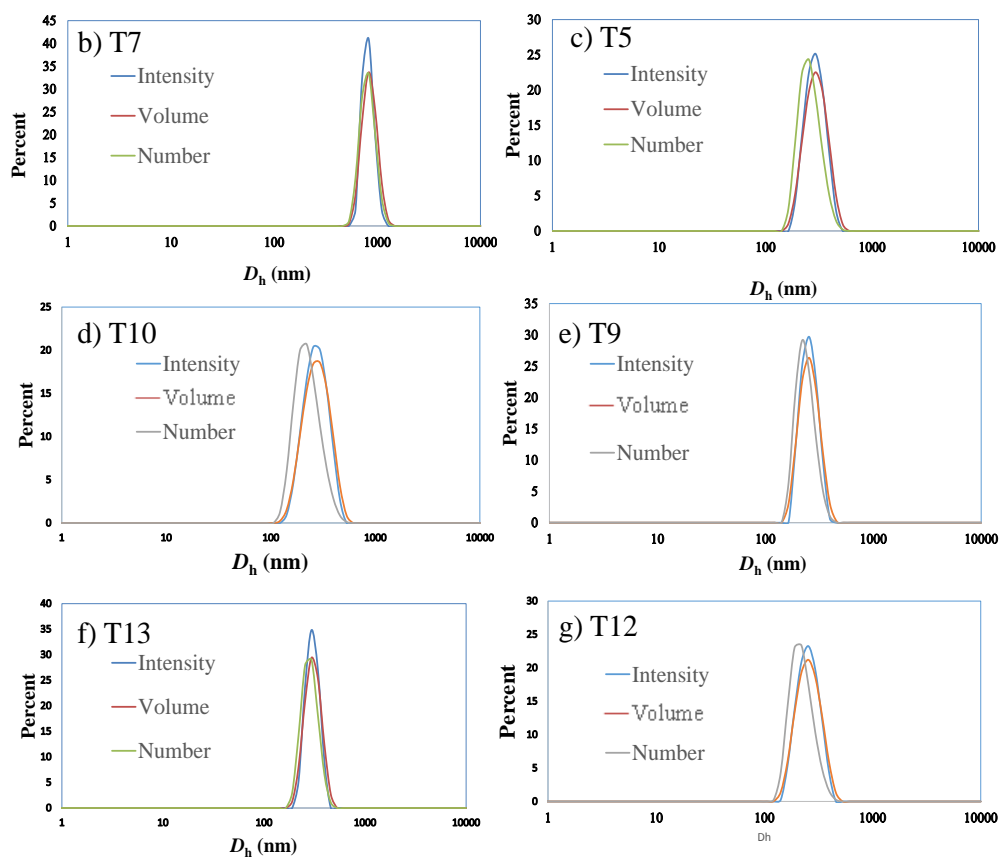


Figure S11. DLS analysis of triblock copolymers PDMA-*b*-PLLA-*b*-PDMA **T5, T7, T9, T10, T12, T13** (Table (a)) and the dispersity trace (b-g) of assemblies achieved from these polymers.

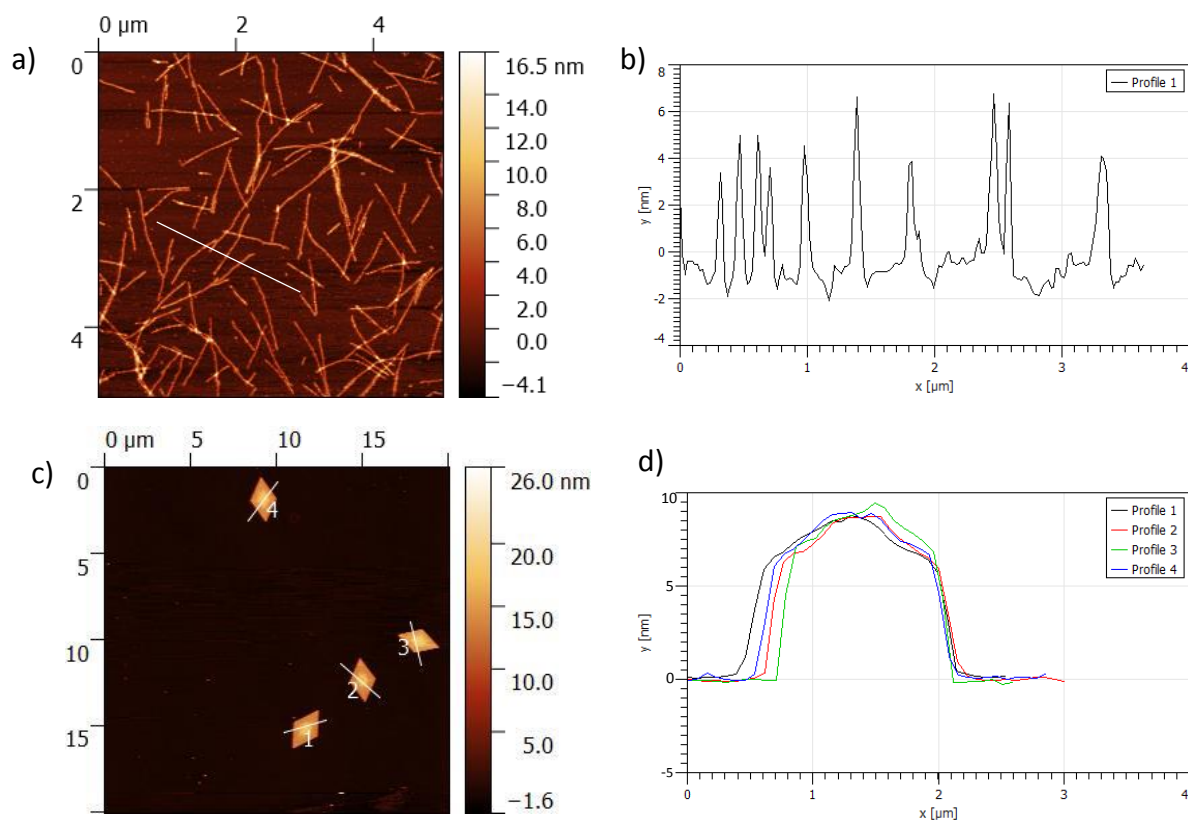


Figure S12. AFM and height profile of triblock copolymer **T8** diamond platelet (c, d) and **T9** cylinders (a, b). Samples were self-assembled in methanol at room temperature with one day aging.

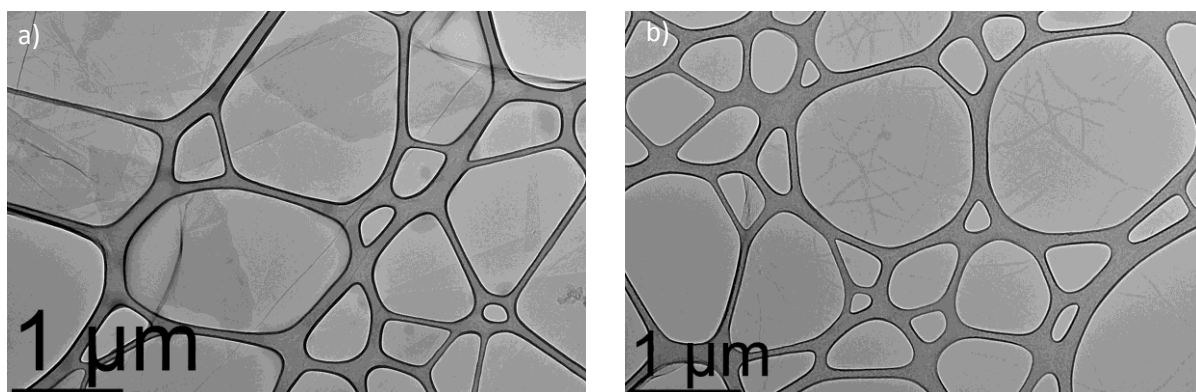


Figure S13. TEM analysis of micelles obtained from the CDSA of triblock copolymers **T4** (a), **T12** (c) prepared by a slow drying method on GO grids.

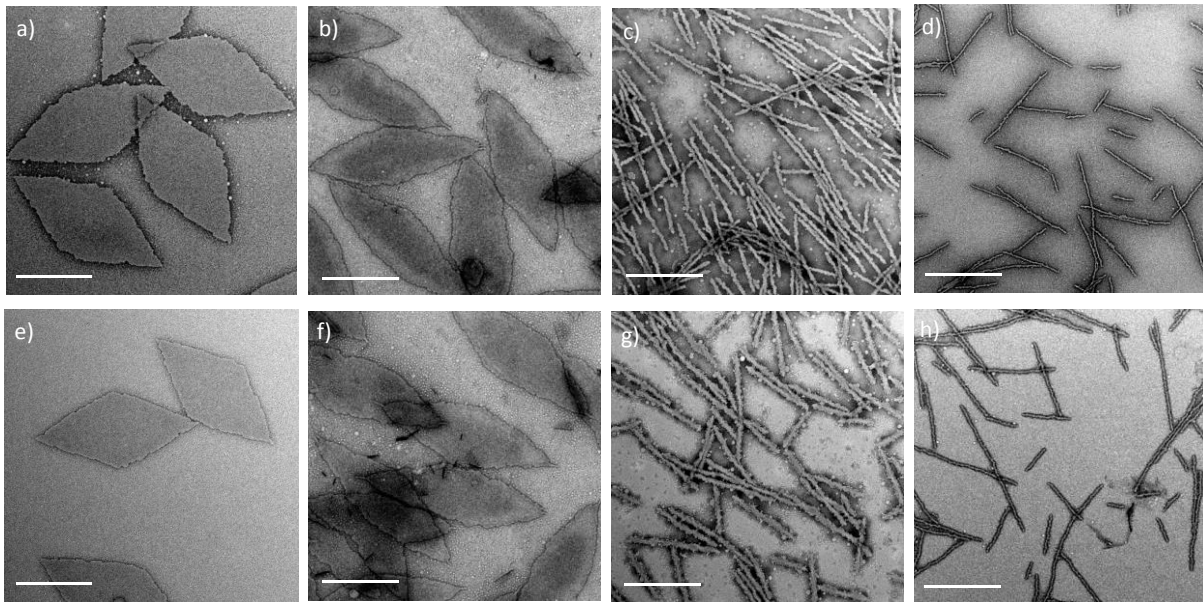


Figure S14. TEM analysis of micelles obtained from the CDSA of triblock copolymers **T8** (a), **T7** (b), **T6** (c), **T5** (d) after aging for one day. TEM characterization of the same samples after one month, **T8** (e), **T7** (f), **T6** (g), **T5** (h), showed the assemblies are stable. Samples were negatively stained using uranyl acetate. Scale bar = 1 μm .

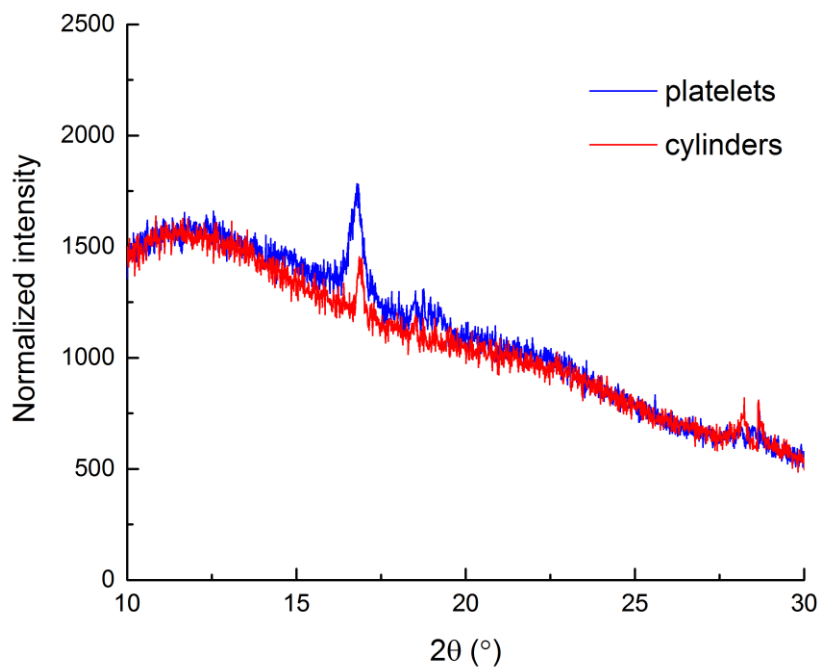


Figure S15. WAXS diffractogram of $\text{PDMA}_{188}\text{-}b\text{-PLLA}_{32}\text{-}b\text{-PDMA}_{188}$ diamond platelets and $\text{PDMA}_{66}\text{-}b\text{-PLLA}_{32}\text{-}b\text{-PDMA}_{66}$ cylinders showing the 2θ peak at *ca.* 16° characteristic of crystalline PLLA. Platelets assembly show stronger crystalline signals than the cylinders.

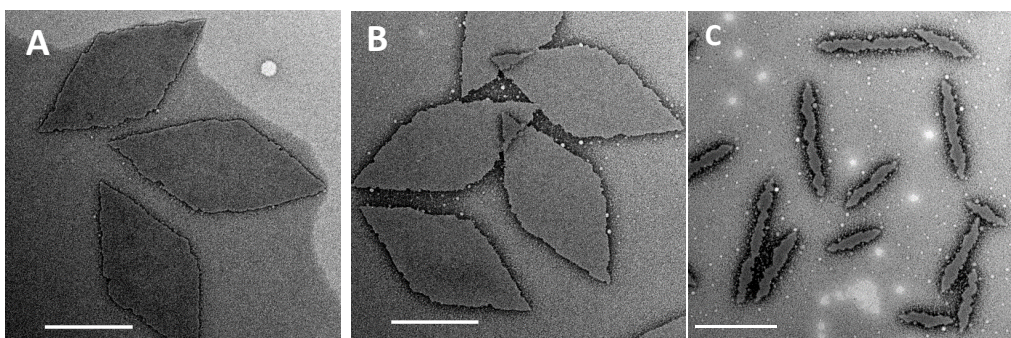


Figure S16. TEM analysis of micelles obtained from the CDSA of triblock copolymers **T4** (A), **T8** (B), **T11** (C). Scale bar = 1 μm .

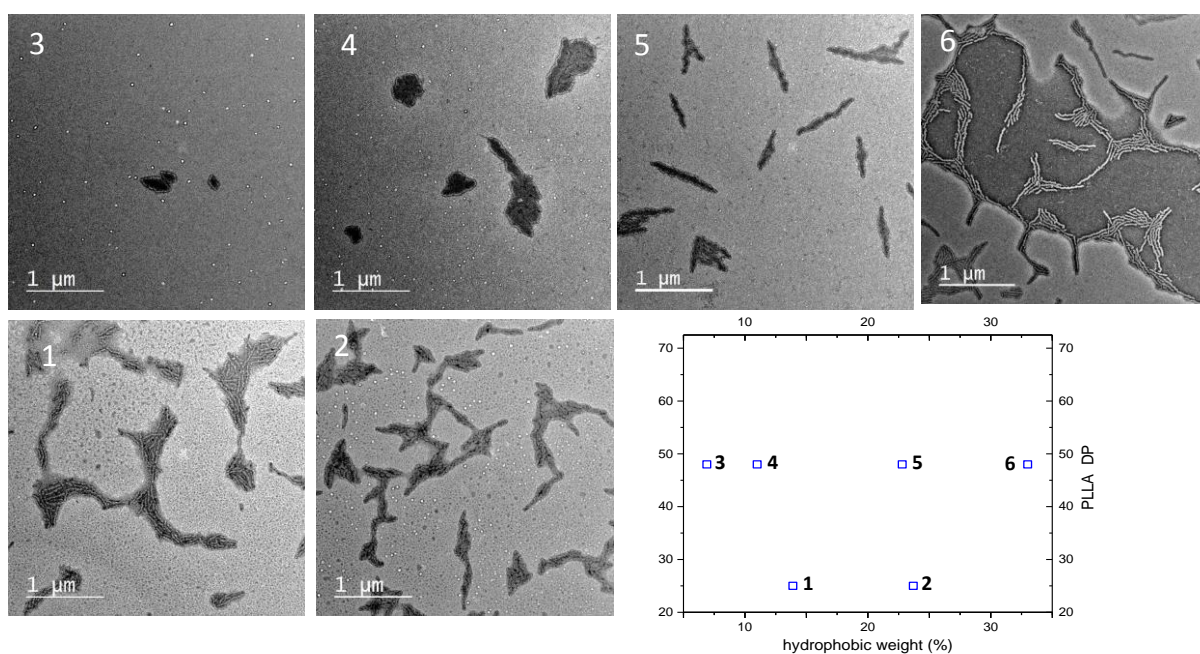


Figure S17. Assemblies achieved from PDMA-*b*-PLLA diblock copolymers **D1(2)**, **D2(1)**, **D3(6)**, **D4(5)**, **D5(4)**, **D6(3)** in methanol at room temperature. Samples were prepared by slow drying on carbon grids and were negatively stained using UA for TEM characterization. Scale bar = 1 μm .

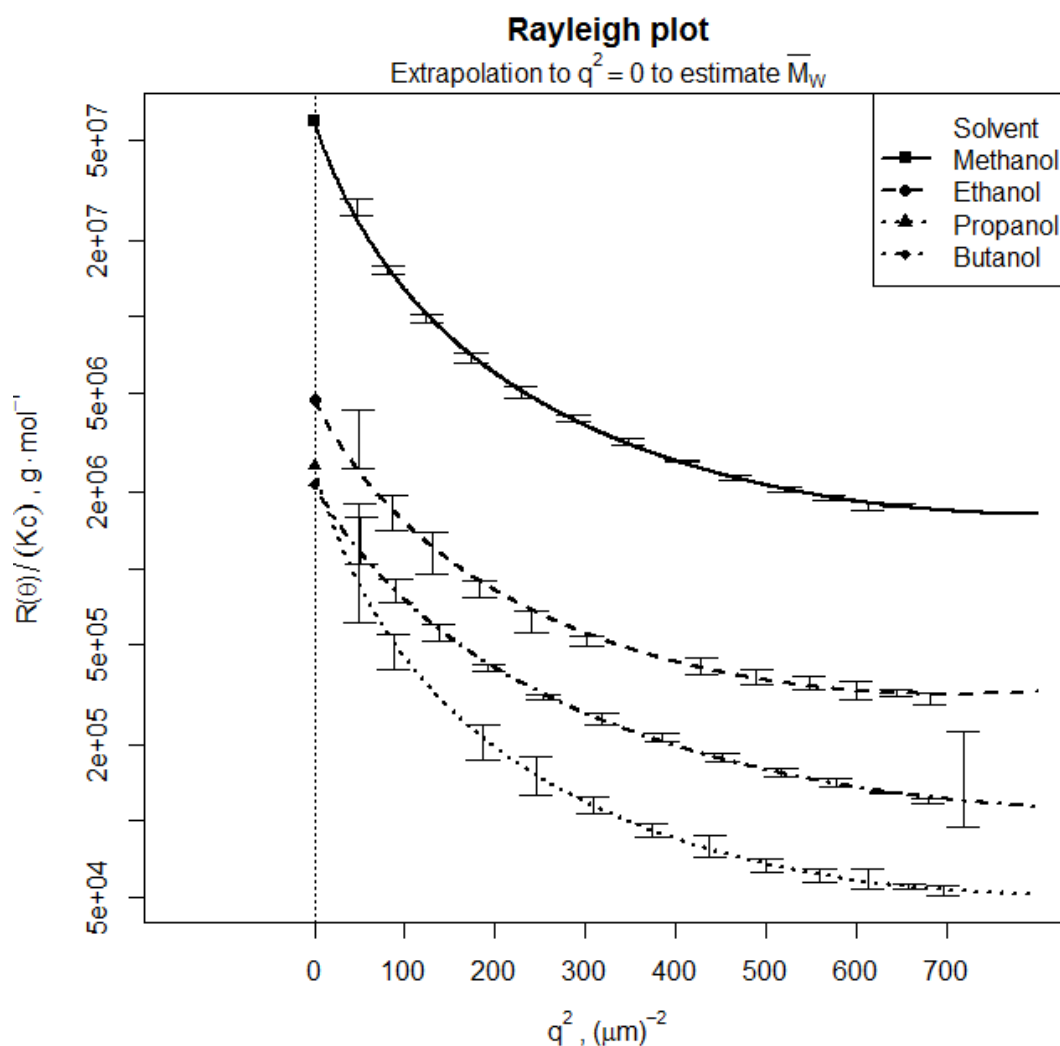


Figure S18. Triblock copolymer PDMA₁₀₅-*b*-PLLA₂₅-*b*-PDMA₁₀₅ was dissolved in four alcohol solvents, *i.e.* methanol, ethanol, *n*-propanol, *n*-butanol at a concentration of 5 g/L. The assembly solution was heated up to achieve a clear solution and then cooled to room temperature and aged for 1 day.

Monitoring the state of assembly via the Tyndall effect provides a convenient qualitative comparison between samples under different solvent conditions but our interpretation relies upon an assumed relationship between intensity of scattered light and particle size. A quantitative analysis of light scattering by particles of size approximately equal to the wavelength of the incident wavelength is provided by Mie theory and appropriate data may be recorded using a goniometer to conduct a 'static light scattering' (SLS) experiment, which utilises a plane-polarised, coherent source of laser light. A SLS experiment calculates excess light scattering attributable to the particles, measuring how this varies according to the measurement angle and sample concentration whilst accounting for the variable optical contrast achieved according to the solvent that is used. The quantity measured is the Rayleigh ratio of the sample, $R(\theta)$, normalised by an optical contrast factor, K , and the sample concentration, c .³

Figure S18 shows the angular dependence of the empirical data R/Kc where all samples have been measured at the same concentration, 5 g/L. The normalised Rayleigh ratio was analysed as a function of scattering length squared, q^2 , with the 'Berry' transformation applied.⁴ Extrapolation to the

intercept at $q^2 = 0$ was achieved by fitting a quadratic model, weighted by the standard error of each data point, which then allowed the mass average molar mass of the particles, \bar{M}_W , to be estimated.

By inspection of the TEM images we assume that both the aggregation number and, consequently, the radius of gyration of a platelet is greater than that of a cylindrical assembly; we choose samples that have been shown to include a mixture of assembly types for analysis. Moreover, we assume that the aggregation number for both kinds of assembly is sufficiently great (i.e. the number density of assembled particles is sufficiently dilute) for the 'apparent' \bar{M}_W to be approximately equal to the value that would be recorded by extrapolation to the limit of dilution. Therefore, we compare \bar{M}_W for samples with different solvent conditions and interpret a greater value as indicating an increased proportion of platelets. This provides a characterisation of the bulk sample that is not available by analysis of TEM images alone.

By inspection of Figure S18, the mass average molar mass for the sample in methanol is approximately an order of magnitude greater than for each of the other solvent conditions, which is consistent with our interpretation of results from the laser pen experiment shown in figure 6 and discussed in the main text. Further refinement of a quantitative approach for characterisation of these heterogeneous samples using the SLS technique is the subject of ongoing work.

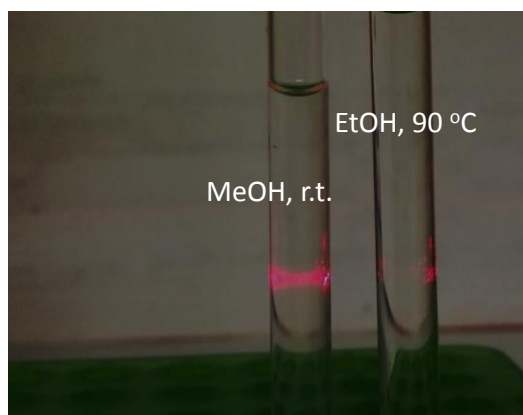


Figure S19. PLLA based triblock copolymer T3 was much easier to achieve CDSA in methanol rather than ethanol judged by Tyndall phenomenon, assembly concentration 5 mg/mL.

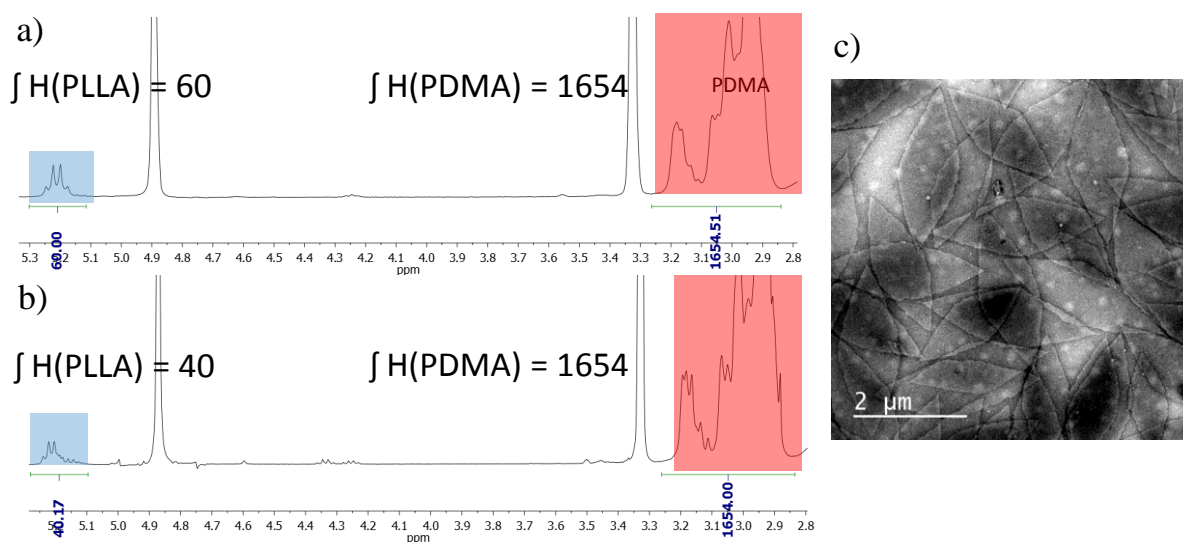


Figure S20. PLLA based triblock copolymer T3 was assembled in d-methanol, ^1H NMR spectra showed the proton signal in poly(L-lactide) was suppressed, the integral value decreased from 60 before aging (a) to 40 after aging for two days (b). The corresponding TEM results showed intact diamonds (c).

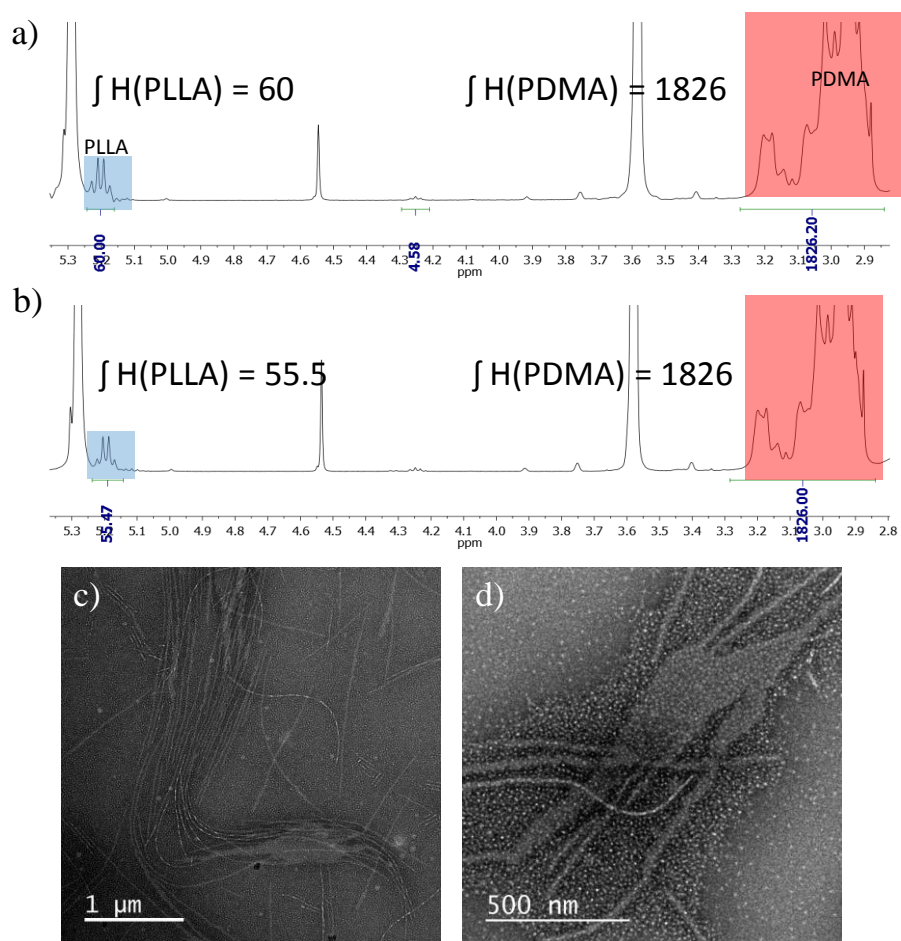


Figure S21. PLLA based triblock copolymer T3 was assembled in d-ethanol, ^1H NMR spectra showed the proton signal in poly(L-lactide) was barely suppressed, when the integral value decreased from 60 before aging (a) to 55.5 after aging for two days (b). The corresponding TEM results showed a blending of spheres, cylinders and incomplete platelet (c, d).

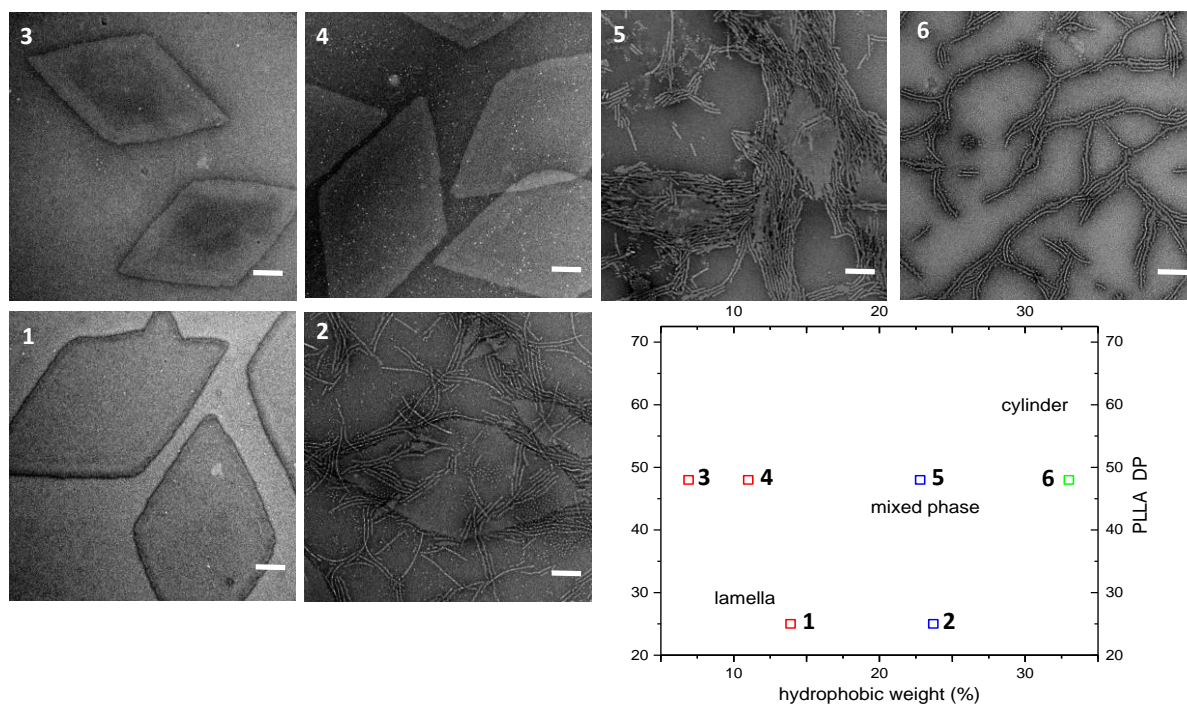


Figure S22. Phase diagram constructed for PDMA-*b*-PLLA diblock copolymers **D1** (2), **D2** (1), **D3** (6), **D4** (5), **D5** (4), **D6** (3). As target PLLA DP and the hydrophobic weight were systematically varied, the achieved morphology changed from lamella (red hollow square) to mixed phase (blue) and to cylinder (green). Samples were prepared by slow drying on carbon grids and were negatively stained using UA for TEM characterization. Scale bar = 1 μ m.

References

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