

Supporting Information

Photo-induced Cu-RDRP in continuous flow without external deoxygenation

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Experimental

Materials

Methyl acrylate (MA, 99%), n-butyl acrylate (n-BA), poly (ethylene glycol) methyl ether acrylate (PEGA₄₈₀), ethyl α -bromoisobutyrate (EBiB, 98%), copper(II) bromide (Cu(II)Br₂, 99%) and dimethyl sulfoxide (DMSO) were purchased from Sigma-Aldrich and used as received. Tris-(2-(dimethylamino)ethyl)amine (Me₆Tren) was synthesized according to the literature and stored in the fridge.¹

Instrumentation

¹H Nuclear Magnetic Resonance.

¹H NMR spectra were recorded on Bruker DPX-300 or DPX-400 spectrometers in deuterated chloroform (CDCl₃) or deuterium oxide (D₂O) obtained from Sigma-Aldrich. Chemical shifts are given in ppm downfield from the internal standard tetramethylsilane. Monomer conversions were determined *via* ¹H NMR spectroscopy by comparing the integrals of monomeric vinyl protons to polymer signals.

Size Exclusion Chromatography

SEC measurements were carried out using THF as the eluent with an Agilent 390-LC MDS instrument equipped with differential refractive index (DRI), viscometry (VS), dual angle light scatter (LS) and dual wavelength UV detectors. The system was equipped with 2 x PLgel Mixed C columns (300 x 7.5 mm) and a PLgel 5 μ m guard column. The eluent was THF with 2% TEA (triethylamine) and 0.01% BHT (butylated hydroxytoluene) additives. Samples were run at 1 mL / min at 30°C. Poly(methyl methacrylate) standards (Agilent EasyVials) were used to create a third order calibration between 550 g mol⁻¹ and 1,568,000 g mol⁻¹. Analytical samples were filtered through a GVHP membrane with 0.22 μ m pore size before injection. Respectively, experimental molar mass ($M_{n,SEC}$) and dispersity (\mathcal{D}) values of synthesized polymers were determined by conventional calibration using Agilent GPC/SEC software (version A.02.01).

Matrix-assisted laser desorption/ionization time-of-flight

MALDI-ToF-MS measurements were conducted using a Bruker Daltonics Ultraflex II MALDI-ToF mass spectrometer, equipped with a nitrogen laser delivering 2 ns laser pulses at 337 nm with positive ion

ToF detection performed using an accelerating voltage of 25 kV. Solutions in tetrahydrofuran (THF) (50 μL) of *trans*-2-[3-(4-*tert*-butylphenyl)-2-methyl-2-propylidene] malononitrile (DCTB) as a matrix (saturated solution), sodium iodide as the cationization agent (1.0 mg mL^{-1}) and sample (1.0 mg mL^{-1}) were mixed, and 0.7 μL of the mixture was applied to the target plate. Spectra were recorded in reflectron mode calibrated with poly(ethylene glycol) monomethyl ether (PEG-Me) 1900 kDa.

Continuous Flow reactor Setup

All the tubings, connections, fittings and ferrules were purchased from Thames Restek. The dual syringe infusion pump was purchased from KD Scientific (model LEGATO[®] 101). The tubing reactors and the connecting tubing were made of PFA (1/16" \times 1.0 mm ID). The length of tubing that was used for the reaction was 3 m. For best mixing results a Cheminert mixing tee 1/4" - 28 for 1/16" tubing, 0.75 mm bore, CTFE was used. As light source, a UVP ultraviolet crosslinker from Analytic Jena (model CL-1000) with $\lambda_{\text{max}} = 365 \text{ nm}$ was used. A septum-sealed glass vial was wrapped with foil, connected with the tubing reactor and used as collection vessel.

Typical procedure for the synthesis of PMA₂₀₀ in continuous flow without deoxygenation.

A 5 mL plastic syringe was charged with a previously sonicated solution of Cu(II)Br_2 (10 mg, 0.16 eq.), Me_6Tren (70 μL , 0.96 eq.) and 5 mL DMSO and a second 5 mL plastic syringe was charged with MA (5 mL, 200 eq.) and EBiB (40 μL , 1 eq.). The two syringes were wrapped with foil and were connected to the female luer adaptors of the tubing and adjusted to the pump. The continuous flow polymerization was left to commence in the UVP crosslinker chamber under $\lambda_{\text{max}}=365 \text{ nm}$. The sample was collected in a sealed and foil-wrapped vial, connected with the tubing reactor (**Figure S1**). Conversions were measured using $^1\text{H NMR}$ in CDCl_3 and SEC analysis was conducted in THF after the samples having been passed through neutral alumina for the removal of copper salts.

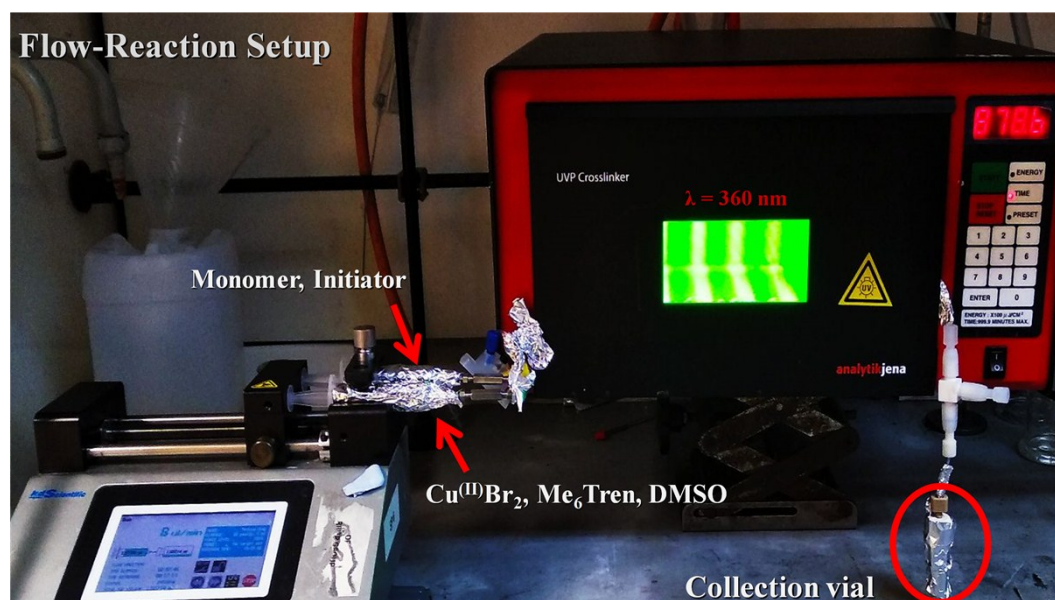


Figure S1. Continuous flow reactor setup.

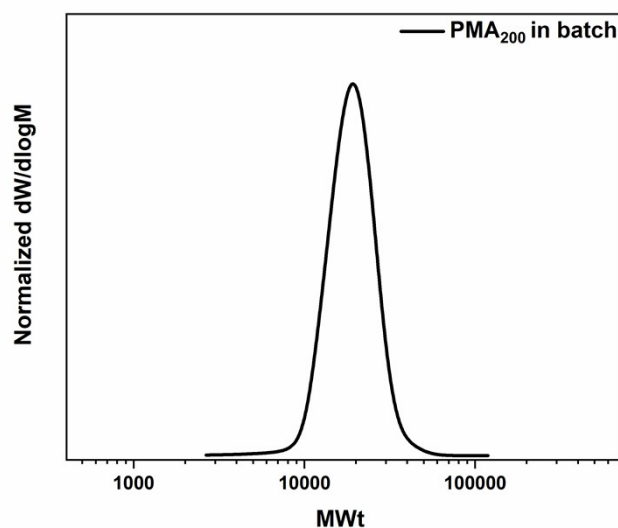


Figure S2. THF-SEC derived molecular weight distributions for targeted PMA₂₀₀ synthesized in batch process without deoxygenation for 3 h in the UVP crosslinker with [MA] : [I] : [Cu(II)Br₂] : [Me₆Tren] = [200] : [1] : [0.02] : [0.12]. The results obtained were: conversion 97%, $\bar{D} = 1.18$ and $M_{n,SEC} = 22,300$ ($M_{n,th.} = 16,900$ g mol⁻¹).

Table S1. ¹H NMR and SEC analysis for all the non-deoxygenated photoinduced Cu-RDRP with different [Cu(II)Br₂] : [Me₆Tren] ratios for PMA₂₀₀.^{a,b}

Entry	[CuBr ₂] : [Me ₆ TREN]	Mon. Conv. ^c (%)	$M_{n,th.}$ (g mol ⁻¹)	$M_{n,GPC}$ ^d	\bar{D}
1	0.02 : 0.12	0	-	-	-
2	0.04 : 0.24	0	-	-	-
3	0.08 : 0.48	46	8,100	11,200	1.16
4	0.16 : 0.96	77	13,500	13,600	1.17
5	0.32 : 1.92	75	13,100	14,000	1.23

^a In all polymerizations, the volume ratio of monomer to solvent was maintained 1 : 1. ^b Flow rate 8 μ L/min. ^c Conversion was calculated *via* ¹H NMR in CDCl₃. ^d Determined by THF SEC analysis and expressed as molecular weight equivalents to PMMA narrow molecular weight standards.

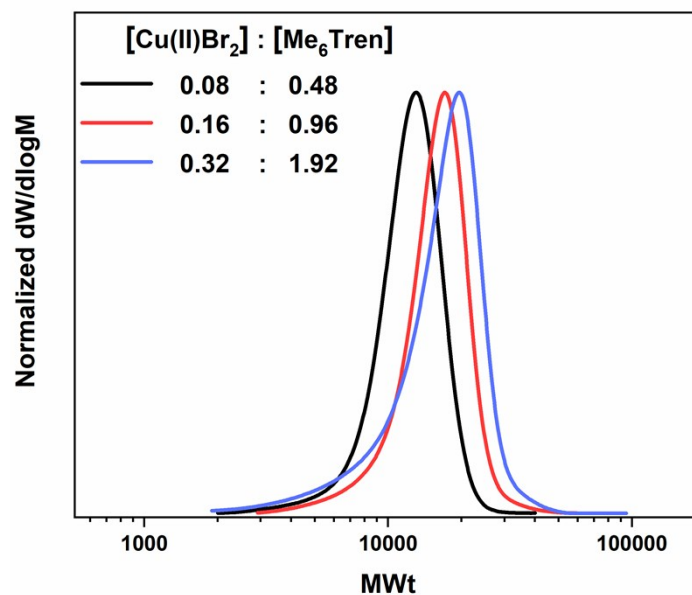


Figure S3. SEC derived molecular weight distributions for targeted PMA₂₀₀ synthesized *via* non-deoxygenated photoinduced Cu-RDRP in continuous flow with different [Cu(II)Br₂] and [Me₆Tren].

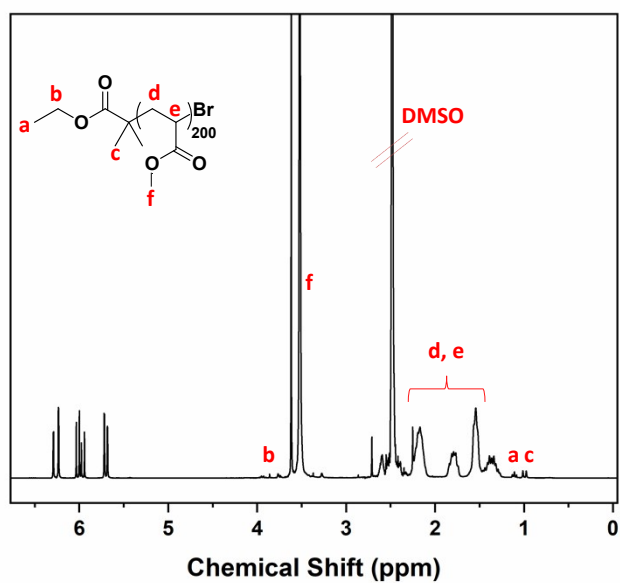


Figure S4. ¹H NMR of targeted PMA₂₀₀ synthesized *via* photoinduced Cu-RDRP in continuous flow without deoxygenation. Conversion (77%) was determined by comparing the integrals of monomeric vinyl protons (~5.7-6.5 ppm) to polymer signal.

Table S2. ^1H NMR and SEC analysis for PMA_{200} passed through the tubing reactor at different timeframes and obtained through photoinduced Cu-RDRP in continuous flow without deoxygenation.^a

Time after first elution	Mon. Conv. ^b (%)	$M_{n,\text{th.}}$ (g mol^{-1})	$M_{n,\text{SEC}}$ ^c	\bar{D}
5 min	84	14,700	15,700	1.18
10 min	84	14,700	15,500	1.19
30 min	85	14,800	15,600	1.18
45 min	85	14,800	15,500	1.17
1 h	85	14,800	15,500	1.19
2 h	85	14,800	15,400	1.15
3 h	85	14,800	15,500	1.18

^a In all polymerizations, the volume ratio of monomer to solvent was maintained 1 : 1. ^b Conversion was calculated *via* ^1H NMR in CDCl_3 . ^c Determined by THF SEC analysis and expressed as molecular weight equivalents to PMMA narrow molecular weight standards.

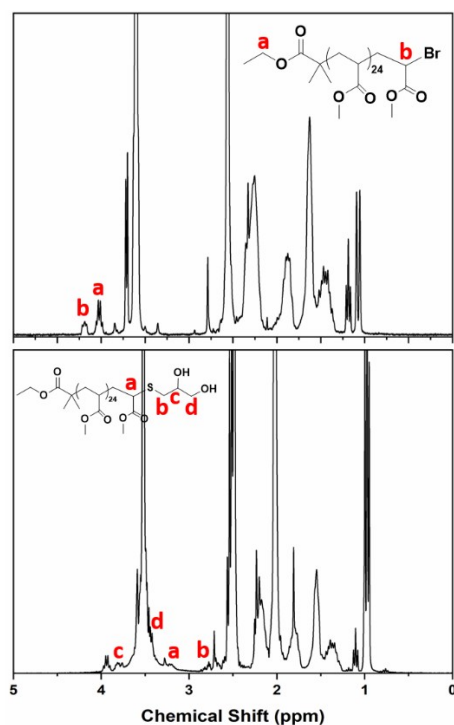


Figure S5: ^1H NMR spectra of the $-\text{Br}$ terminated PMA_{25} (top) and thioglycerol terminated PMA_{25} (bottom).

Table S3. ^1H NMR, SEC analysis and flow rates for the PMA with different DPs obtained through photoinduced Cu-RDRP in continuous flow without deoxygenation.^a

DP	Flow rate ($\mu\text{L}/\text{min}$)	Residence time	Mon. Conv. ^b (%)	$M_{n,\text{th.}}$ (g mol^{-1})	$M_{n,\text{GPC}}^c$	\mathcal{D}
25	6	3 h 20 min	99	2,300	2,300	1.12
50	6	3 h 20 min	97	4,400	4,300	1.12
200	6	3 h 20 min	85	14,800	14,300	1.15
400	3	6 h 40 min	72	25,000	26,400	1.28

^a In all polymerizations, the volume ratio of monomer to solvent was maintained 1 : 1. ^b Conversion was calculated *via* ^1H NMR in d-CHCl_3 . ^c Determined by THF-SEC analysis and expressed as molecular weight equivalents to PMMA narrow molecular weight standards.

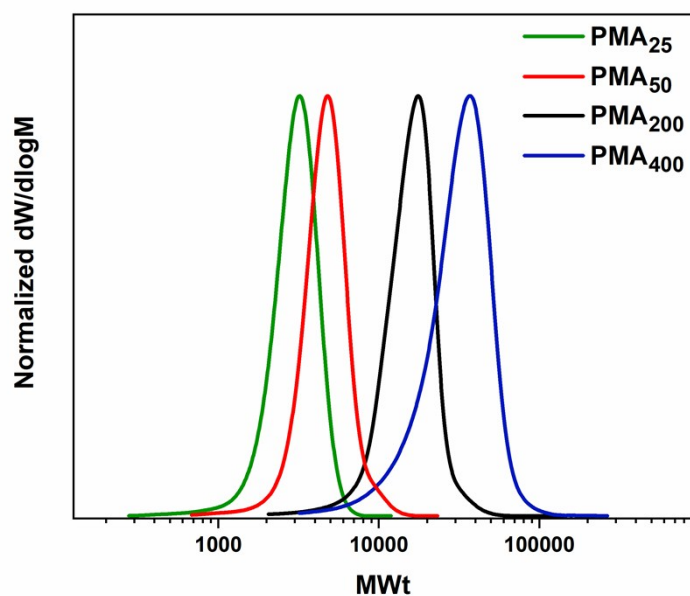


Figure S6. THF-SEC derived molecular weight distributions of PMA with targeted $\text{DP}_n=25\text{-}400$ synthesized *via* non-deoxygenated photoinduced Cu-RDRP in continuous flow

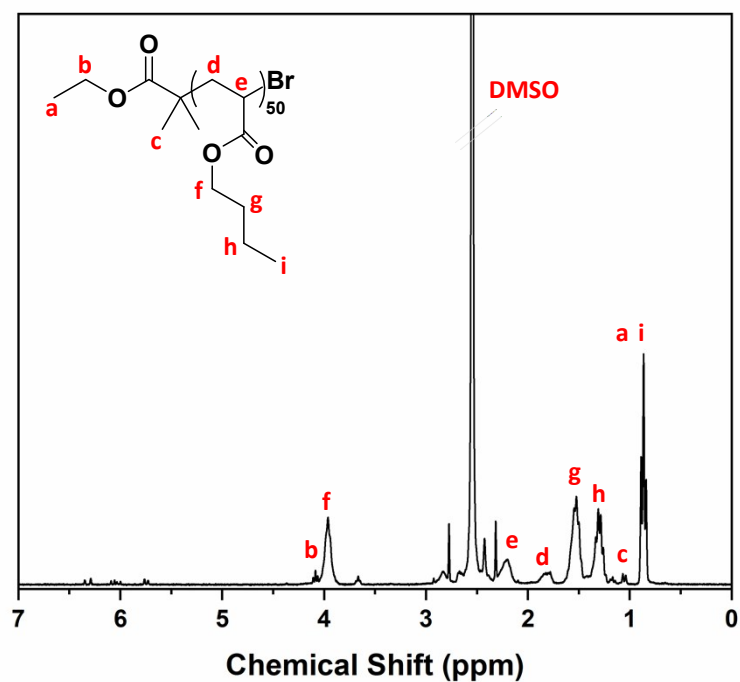


Figure S7. ¹H NMR of P(*n*-BA)₅₀ synthesized *via* photoinduced Cu-RDRP in continuous flow without deoxygenation. Conversion (95%) was determined by comparing the integrals of monomeric vinyl protons (~5.7-6.5 ppm) to polymer signal.

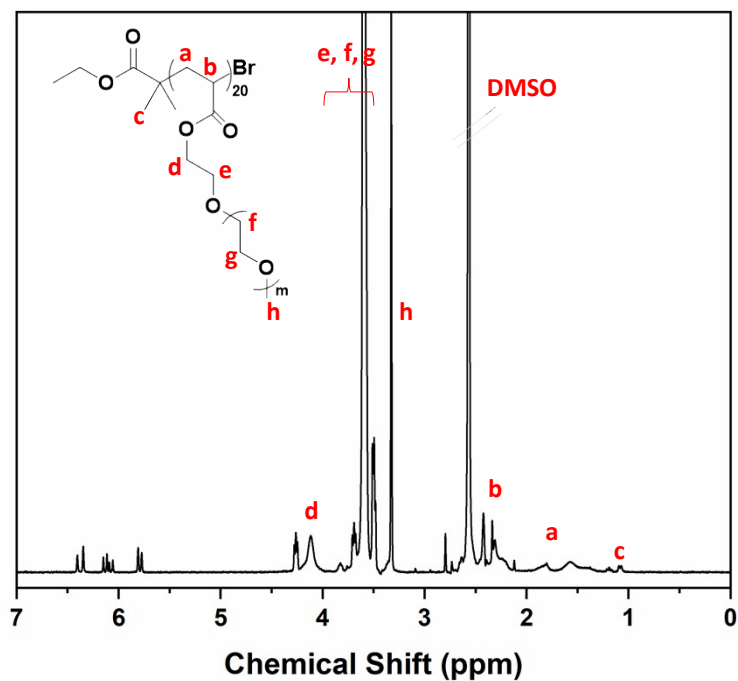


Figure S8. ¹H NMR of targeted P(PEGA₄₈₀)₂₀ synthesized *via* photoinduced Cu-RDRP in continuous flow without deoxygenation. Conversion (80%) was determined by comparing the integrals of monomeric vinyl protons (~5.7-6.5 ppm) to polymer signal.

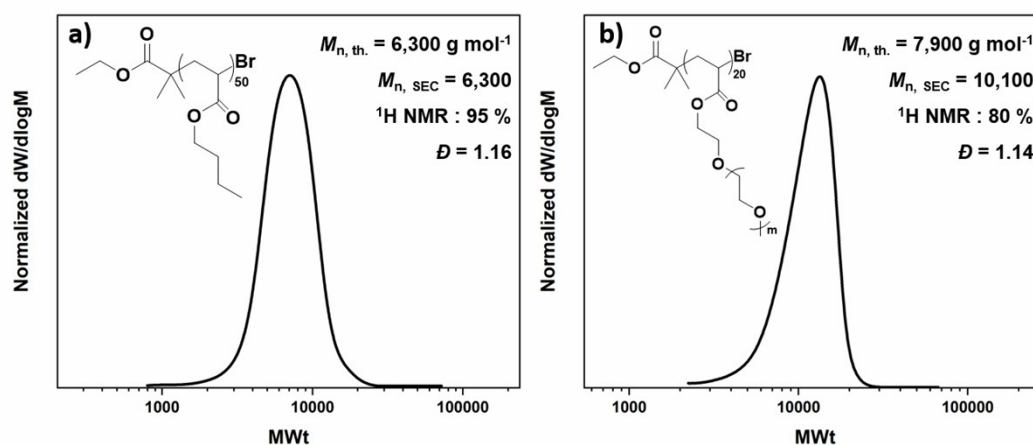


Figure S9 THF-SEC derived molecular weight distributions and molecular characteristics of **a)** $P(n\text{-BA})_{50}$, **b)** targeted $P(\text{PEGA}_{480})_{20}$ synthesized *via* non-deoxygenated photoinduced Cu-RDRP in continuous flow.

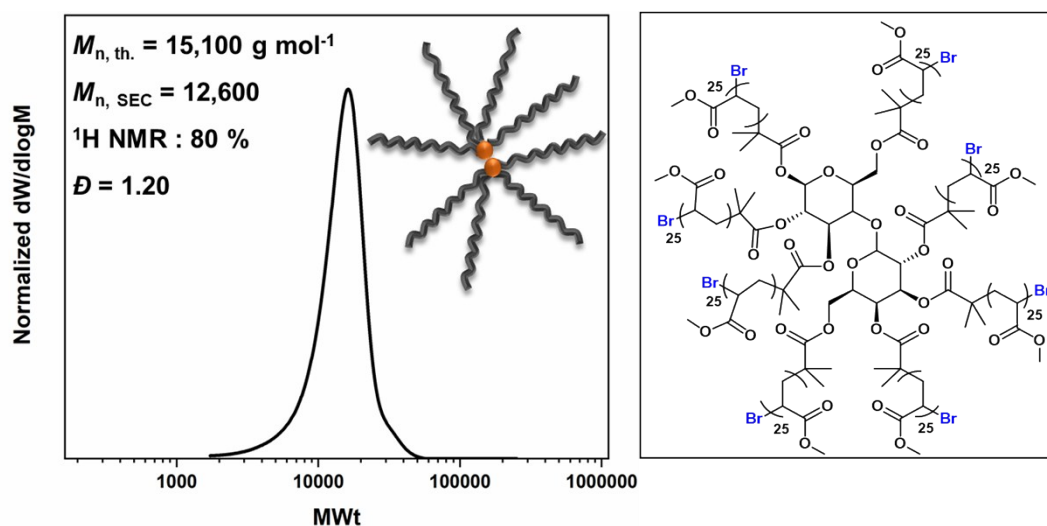


Figure S10. THF-SEC derived molecular weight distributions, molecular characteristics and scheme of the 8-arm PMA_{200} star polymer synthesized *via* non-deoxygenated photoinduced Cu-RDRP in continuous flow with $[\text{Cu}(\text{II})\text{Br}_2] : [\text{Me}_6\text{Tren}] = [0.16] : [0.96]$ and $6 \mu\text{L}/\text{min}$ flow rate.

References

1. M. Ciampolini and N. J. I. C. Nardi, 1966, 5, 41-44.