Electronic Supplementary Information

Facile Synthesis of Photo-cleavable Polymers via Passerini Reaction

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EXPERIMENTAL

Materials. 1,6-Hexanedioic acid (Sinopharm Chem. Reagent; >99.5%), *o*-nitrobenzaldehyde (Sinopharm Chem. Reagent; A.R.), 1,6-diisocyanohexane (Aldrich; >98%) and 3,3'-dithiodipropionic acid (Acros, 99%) were used as received. Carboxylic acid terminated poly(ethylene glycol) [1] ($M_{n,\ GPC}$ =2700, M_w/M_n = 1.03, $M_{n,NMR}$ =2080, DP_{NMR} =45), propargyl isocyanoacetamide [2] and azido-terminated poly(tert-butyl acrylate) [2] (P*t*BA$_{25}$-N$_3$, $M_{n,\ GPC}$ =3300, M_w/M_n = 1.17, $M_{n,NMR}$ =3400, DP_{NMR} = 25) were synthesized according to literature methods, respectively. Other reagents were commercially obtained from Beijing Chem. Co. and used without further purification.

Characterizations. ^{1}H NMR (400 or 300 MHz) and ^{13}C NMR (100.5 or 75 MHz) spectra were recorded in $CDCl_3$ or DMSO-d_6 on a Bruker-400 spectrometer or Varian-300 spectrometer with tetramethylsilane (TMS) as the internal reference for chemical shifts. Polymer characterization was analyzed by different GPC systems. For **P1**, **P2** and their degradation products, Mn and PDI were measured by GPC performed at 50 °C using a SSI pump connected to Wyatt Optilab DSP differential refractometer detectors with DMF containing 0.02 M LiBr as the eluent at a flow rate of 1.0 mL/min.

Polystyrene standards were used for the calibration. For **P4** and its degradation products, Mn and PDI were determined by GPC performed at 35 °C using a Waters 1525 binary HPLC pump connected to a Waters 2414 refractive index detector with THF as the eluent at a flow rate of 1.0 mL/min. Monodisperse linear PS standards were used for calibration. UV-vis spectra were recorded on a Shimadzu 2101 UV-vis spectrometer in a 1 cm quartz cell. All the UV irradiation experiments were carried out under the Spectroline SB-100P/F high-intensity UV lamp (100W, 365nm). The samples were put on a platform at a distance of 5 cm under the Lamp.

Thermal gravimetric analysis (TGA) was carried out using a Q600-SDT thermogravimetric analyzer (TA Co., Ltd.) with nitrogen purging rate set at 50 mL/min. Measurements were conducted from room temperature to 500 °C at a heating rate of 10 °C/min. Calorimetric measurements were performed using a Q100 differential scanning calorimeter (TA Co., Ltd.) with nitrogen purging rate set at 50 mL/min. The program was set to finish two cycles in a temperature range of -80 to 190 °C at a heating/cooling rate of 10 °C/min. Data of endothermic curve were acquired from the second scan data for each polymer sample. TA Universal Analysis software was applied for data acquisition and processing in the two measurements.

Synthesis of photo-cleavable polymer P1

A mixture of 1,6-Hexanedioic acid (146.1 mg, 1 mmol), *o*-nitrobenzaldehyde (453 mg, 3 mmol) and 1,6-diisocyanohexane (136.5 mg, 1 mmol) in CH_2Cl_2 (1 mL) was stirred at 30 °C for 4 days. Finally, the reaction mixture was precipitated into diethyl ether for three times, and the obtained polymer was then dried under vacuum overnight.

Synthesis of photo- and redox dually cleavable polymer P2

A mixture of 3,3'-dithiodipropionic acid (210.3 mg, 1 mmol), *o*-nitrobenzaldehyde (453 mg, 3 mmol) and 1,6-diisocyanohexane (136.5 mg, 1 mmol) in CH_2Cl_2 (1 mL) was stirred at 30 °C for 4 days. Finally, the reaction mixture was precipitated into diethyl ether for three times, and then the obtained polymer was dried under vacuum overnight

(550 mg, 85%).

Synthesis of the dually end-functionalized PEG P3

A mixture of carboxylic acid terminated poly(ethylene glycol) (2.1 g, 1 mmol), *o*-nitrobenzaldehyde (0.38 g, 2.5 mmol) and propargyl isocyanoacetamide (0.19 g, 1.5 mmol) was stirred in THF (10 mL) at 30 °C for 24 h. The reaction mixture was evaporated to dryness on a rotary evaporator, and then dissolved in 50 mL of 0.5 M aqueous HCl solution to remove the excess propargyl isocyanoacetamide. The aqueous solution was extracted with CH_2Cl_2 (3 ×50 mL) and the obtained organic fractions were dried over anhydrous Na_2SO_4. After removing all the solvents, the residues were dissolved in THF and precipitated into diethyl ether for three times. PEG functionalized with one *o*-nitrobenzyl group and one alkynyl group was obtained as a white powder after drying in a vacuum oven overnight (2 g, 87%). $M_{n,\,GPC}$ =2,800, M_w/M_n =1.04. $M_{n,\,NMR}$=2,300, DP_{NMR}=45.

Synthesis of the photo-cleavable block copolymer P4

Photo-cleavable PEG-*b*-P*t*BA was prepared by the click reaction between the above synthesized PEG and P*t*BA-N_3. A mixture of the dually end-functionalized PEG (46 mg, 0.02 mmol), P*t*BA-N_3 (72 mg, 0.024 mmol), and PMDETA (5 µL, 0.024 mmol) was dissolved in DMF (2 mL). After one freeze-pump-thaw cycle, CuBr (3.46 mg, 0.024 mmol) was charged into the tube under the protection of nitrogen. The reaction mixture was degassed via three freeze-pump-thaw cycles. After 24 h at 60 °C, the mixture was diluted with THF and passed through a short Al_2O_3 column. The obtained solution was concentrated and precipitated into cold hexane to give PEG-*b*-P*t*BA (86 mg, 81%).

General procedure for the degradation of the photo-cleavable polymers

The solutions of polymers in CH_2Cl_2 (1 mL, 0.04 mg/mL) were subjected to UV irradiation for different times. The process was monitored by UV-Vis spectra. For the block copolymer PEG-*b*-PtBA, a higher polymer concentration (0.1g/L) was used.

The solutions of polymers in CH_2Cl_2 (1 mL, 1 mg/mL) were subjected to UV irradiation for different times. The resulted mixture was concentrated and measured by GPC.

For reductive degradation, the solution of **P2** in CH_2Cl_2 (1 mL, 1 mg/mL) was added with DTT. After being stirred at room temperature for 15 min., the mixture was concentrated and then the residue was measured by GPC.

Table S1 Passerini MCP using *O*-nitrobenzaldehyde

Entry	Aldehyde /eq. [a]	Conc./M [b]	t (h)	Yield/%[c]	M_n/kDa[d]	PDI[d]
1	2	1.0	24	84	0.5	1.39
2	3	0.5	24	80	0.9	1.42
3	3	1.0	24	83	10.1	1.47
4	3	1.0	48	90	11.3	1.48
5	3	1.0	96	89	14.8	1.34

[a] The molar ratio of *o*-nitrobenzaldehyde to 1,6-hexanedioic acid. [b] Here shows the concentration of 1,6-hexanedioic acid, which is equal to that of 1,6-diisocyanohexane. [c] Determined after precipitation into ethyl ether and vacuum dryness. [d] Measured by GPC using DMF as the eluent.

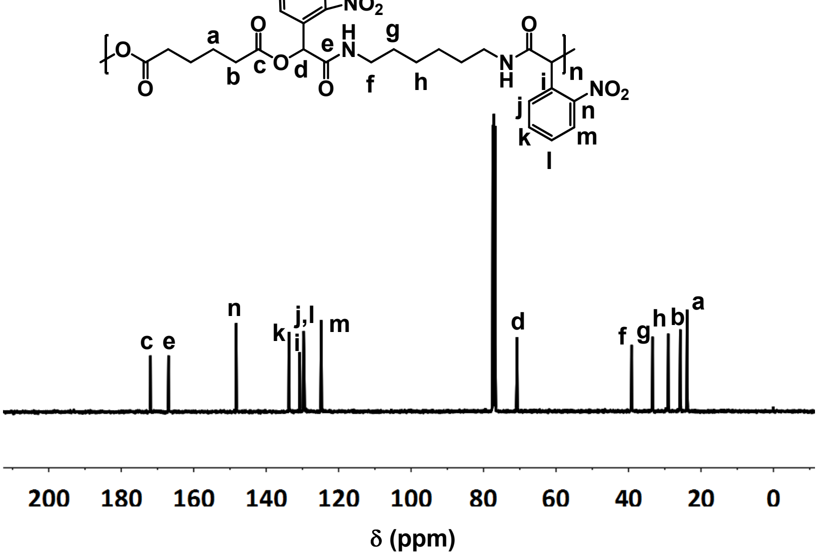

Fig. S1 ^{13}C NMR spectrum of the photo-cleavable polymer **P1** (M_n = 14.8 kDa, PDI = 1.34).

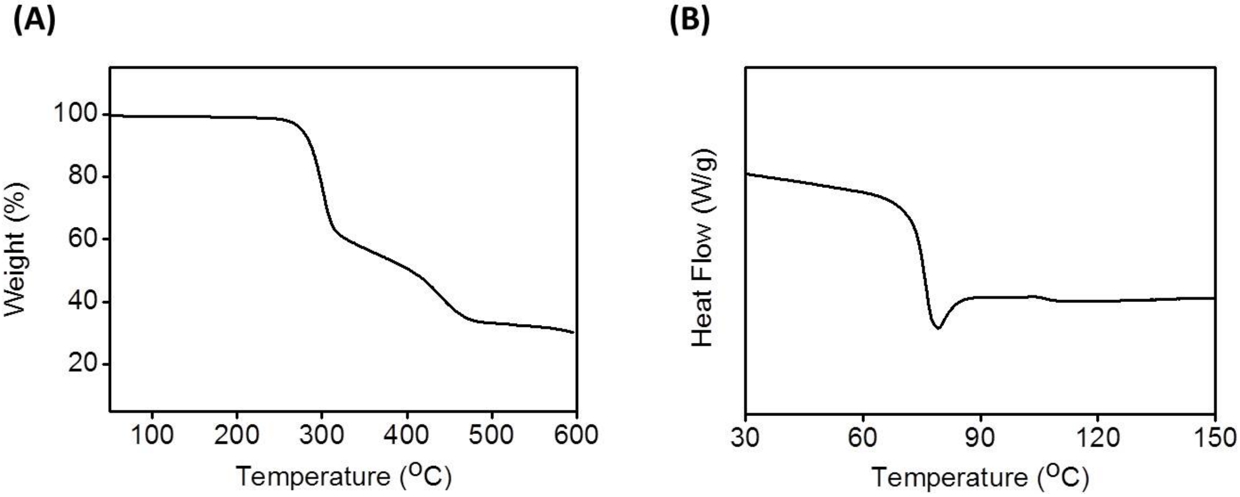

Fig. S2 TGA (A) and endothermic DSC thermograms (B) of **P1** (M_n = 14.8 kDa, PDI = 1.34).

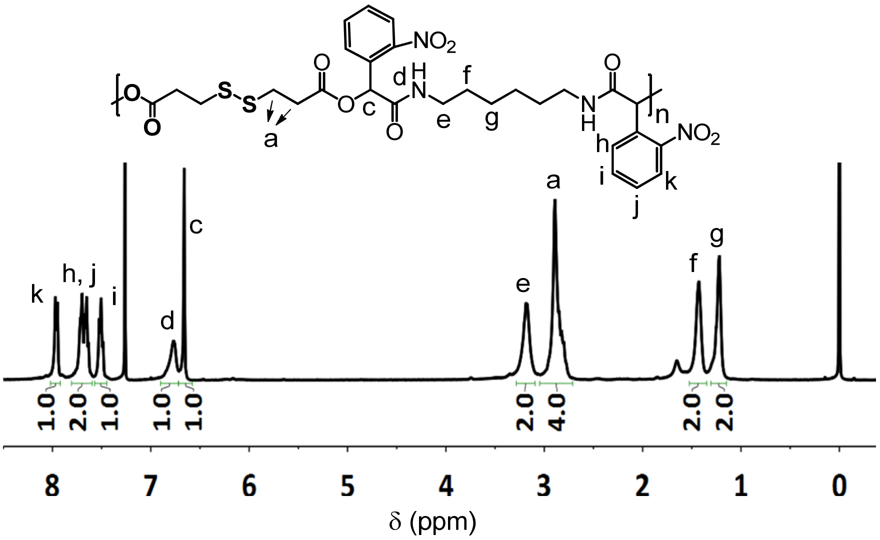

Fig. S3 ^{1}H NMR spectrum of the photo and redox dually cleavable polymer **P2** (M_n = 15.7 kDa, PDI = 1.80).

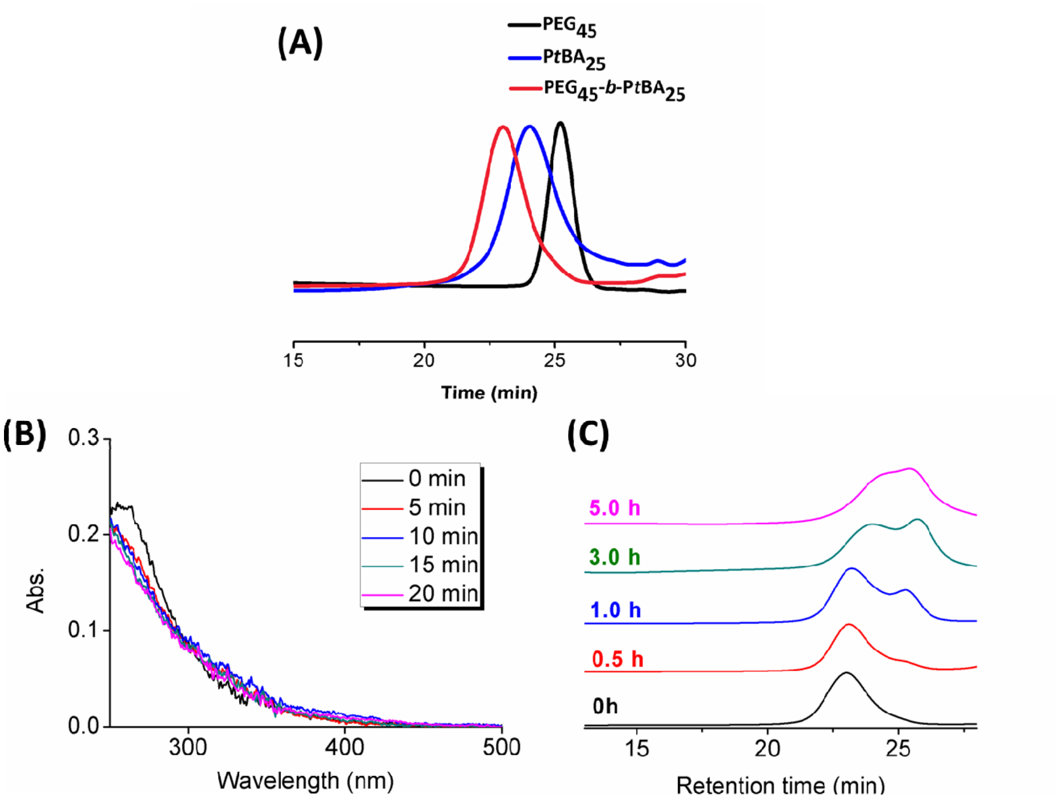

Fig. S4 (A) GPC traces of PEG_{45}, $PtBA_{25}$, **P4** (PEG_{45}-*b*-P*t*BA_{25}). (B) UV-Vis absorption spectra of **P4** in CH_2Cl_2 (0.1 mg/ml) recorded as a function of UV exposure time (365nm, 100W). (C) GPC traces of **P4** in CH_2Cl_2 (1 mg/ml) recorded as a function of UV exposure time (365nm, 100W). (Mn = 7.1 kDa, PDI = 1.14).

References

1. C. Y. Hong, Y. Z. You and C. Y. Pan, *J. Polym. Sci., Part A: Polym. Chem.*, 2004, **42**, 4873.
2. L. Li, X. W. Kan, X. X. Deng, C. C. Song, F. S. Du, Z. C. Li. *J. Polym. Sci. Part A: Polym. Chem.*, 2013, **51**, 865.