Supporting Information for

Designing a Main-Chain Visible-Light-Labile Picolinium-Caged Polymer and Its Biological Applications

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Materials. Poly(ethylene glycol) bis(carboxymethyl) ether (Mw = 250), poly(ethylene glycol) (Mw = 200), Poly(ethylene glycol) methyl ether (Mw = 2000) were purchased from Sigma-Aldrich. 4-pyridinemethanol was purchased from Adamas. Tris(2,2'-bipyridyl) ruthernium (II) was obtained from ACROS. Other agents were analytically pure and used without further purification. In vitro cytotoxicity analysis. human bone mesenchymal stem cells (BMSCs) were collected from the redundant cancellous bone amputated during orthognathic surgery at Peking university hospital of stomatology in China.

Characterizations. ^{1}H NMR spectra were recorded on a 400 MHz spectrometer (Bruker AM-400). Mass spectral and analytical data were obtained via the Matrix Assisted Laser Desorption Ionization-Time of Flight/Time of Flight Mass

Spectrometer (AB SCIEX-5800). Fourier Transform Infrared spectra (FT-IR) were recorded on EQUINOX-55 spectrometer in the range of 4000–400 cm^{-1}. Thermal stability was determined with a thermogravimetric analyzer (Q600 SDT) over a temperature range of 25~400 ^oC at a heating rate of 10 $^oC \cdot min^{-1}$ under nitrogen atmosphere. The calorimetric measurements were carried out on a Mettler Toledo DSC1 differential scanning calorimeter as heating rate of $^oC \cdot min^{-1}$ from -50 to 40 ^oC. The cyclic voltammetry measurement was carried out on an electrochemical workstation of CHI660E. The intrinsic viscosity ([η]) was measured by an Ubbelohde-type flow capillary viscometer. The light intensity was measured by a FZ-A digital LED meter. Gel permeation chromatography (GPC) measurement was performed on waters 410 using water and DMF as the eluents.

Synthesis of compound 1. Poly(ethylene glycol) bis(carboxymethyl) ether (Mw = 250) (5.0 g, 20 mmol), 4-Pyridinemethanol (5.0 g, 45.8 mmol) and 4-dimethylaminopyridine (DMAP) (1.0 g, 8.18 mmol) was dissolved in 100 mL of CH_2Cl_2 at 0 ^oC. Then N-Ethyl-N'-(3 dimethylaminopropyl) carbodiimide hydrochloride (EDC) (12.5 g, 65.2 mmol) was added in batches and stirred at room temperature for 24 h. The reaction was washed with saturated $NaHCO_3$ solution and brine, respectively. The organic phase is dried with anhydrous $MgSO_4$ and evaporated under vacuum to obtain **1** as red-brown liquid (7.41 g, yield 88%). ^1H NMR (400 MHz, $CDCl_3$): 8.66~8.58 (1 H, m), 7.33~7.23 (1 H, m), 5.22 (1 H, s), 4.30~4.25 (1 H, m), 3.83~3.66 (2 H, m).

Synthesis of compound 2. PEG_{200} (20 g, 103 mmol) was dissolved in THF (70 mL) and added to a 250 mL round-bottom flask equipped with a magnetic stir bar and placed in an ice bath. Sodium hydroxide (15 g, 375 mmol) was then dissolved in deionized water (70 mL) and added to the flask while stirring the THF solution. *p*-toluenesulfonyl chloride (*p*-TsCl) (45 g, 230 mmol) was dissolved in THF (70 mL) and added to a volumetric dropping funnel, which was then equipped to the neck of

the 250 mL flask. *p*-TsCl was added dropwise for approximately 1 h, after which time the reaction was stirred for an additional 24 h at room temperature. Then the reaction was quenched with 1.2 M HCl (400 mL) and the product was extracted into EtOAc (200 mL) and washed with deionized water (2×250 mL), saturated $NaHCO_3$ (2×250 mL), and deionized water (2×250 mL). The organic phase was then dried over anhydrous $MgSO_4$ and filtered. EtOAc was removed via rotary evaporation followed by vacuum for 12 h at room temperature to afford tosylation of poly(ethylene glycol) (PEG-OTs) as a clear, viscous oil (44.1 g, yield 80%).

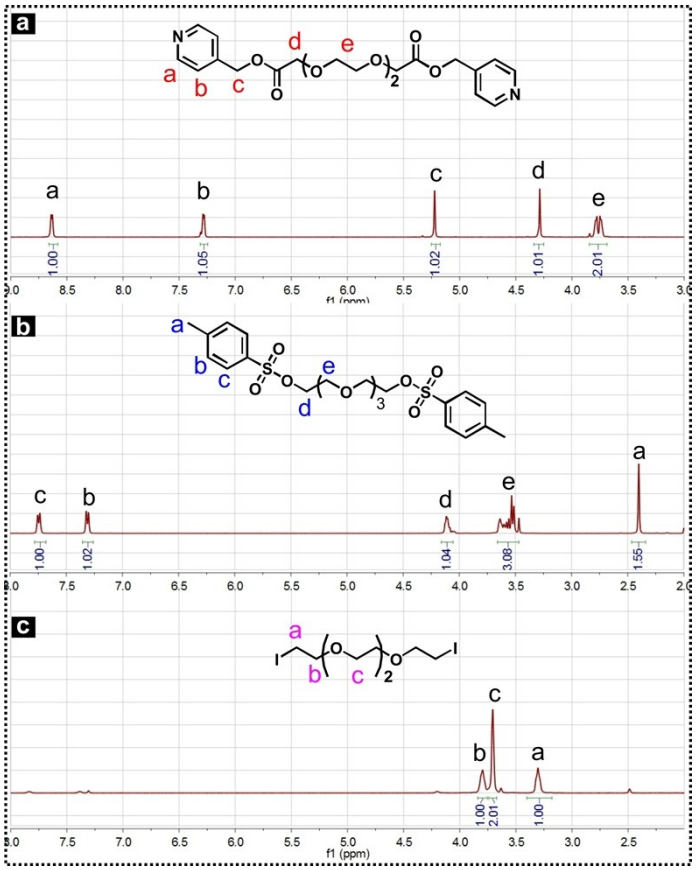


Figure S1. ^{1}H-NMR spectra of (a) **1**, (b) tosylation of poly(ethylene glycol), and (c) **2** in $CDCl_3$, respectively.

PEG-OTs (44.1 g, 88 mmol) was dissolved in acetone (250 mL) and added to a 500 mL round-bottom flask equipped with a magnetic stir bar. With the solution stirring, NaI (33 g, 220 mmol) was dissolved in acetone (200 ml) and added, followed with a white precipitate immediately. The flask was covered with aluminum foil and stirred for 24 h at room temperature before filtering to remove the solid precipitate.

Acetone was then removed from the filtrate via rotary evaporation and the product was extracted by Et_2O (200 mL). The solution was then filtered over a flash silica column and Et_2O was removed via rotary evaporation to afford **2** as a clear yellow liquid (28 g, yield 75%). ^{1}H NMR (400 MHz, $CDCl_3$): 3.80 (1 H, s), 3.71 (2 H, s), 3.30 (1 H, s).

Synthesis of MCPP. Compound **1** and **2** (1:1, molar ratio) were dissolved together in dried CH_3CN, and refluxed for 48 h under N_2 atmosphere. Then the solvent was removed via rotary evaporation followed by vacuum for 12 h at 50 °C to afford MCPP as viscous dark red solid. ^{1}H NMR (400 MHz, D_2O): 8.83~8.65 (1 H, m), 7.98 (1 H, d, J = 5.2 Hz), 5.48 (1 H, s), 4.37 (1 H, s), 3.98~3.88 (1 H, m), 3.81~3.37 (5 H, m).

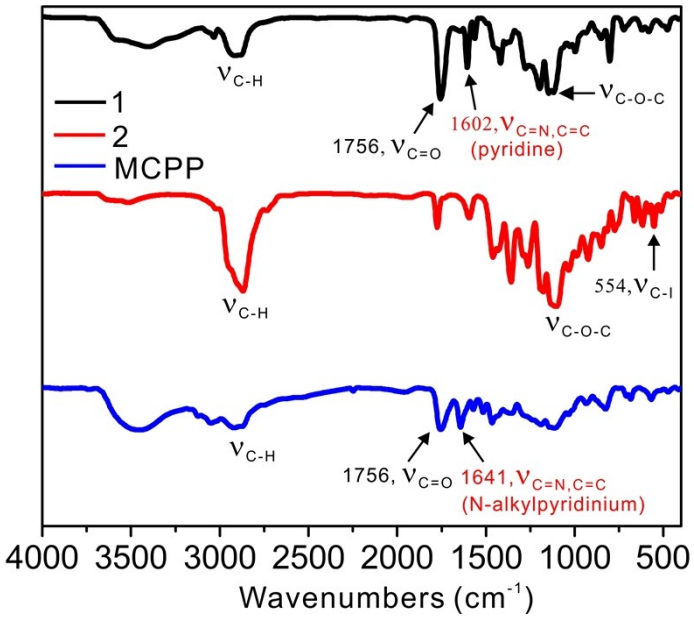


Figure S2. FT-IR spectra of **1**, **2** and MCPP.

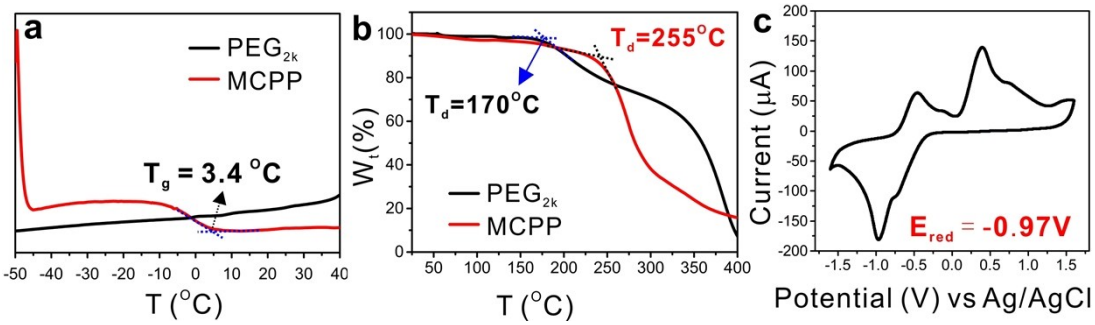


Figure S3. The characterizations of (a) differential scanning calorimetry (DSC) and

(b) thermogravimetric analysis (TGA) of MCPP and PEG_{2k}. (c) Cyclic voltammetry (CV) of MCPP in the solution of $LiClO_4$ in dried MeCN (0.2 M).

Table S1. The intrinsic viscosity ([η]) of MCPP that were synthesized at different concentrations and solvents.

Solvents	Concentrations of polymer ($g \cdot mL^{-1}$)	**1 / 2** ($mol \cdot mL^{-1}$)	[η] ($mL \cdot g^{-1}$)
CH_3CN	0.1	0.124 / 0.121	1.4
	0.2	0.248 / 0.242	8.5
	0.4	0.496 / 0.484	4.1
DMF	0.2	0.248 / 0.242	2.9
DMSO	0.2	0.248 / 0.242	1.5

Visible light degradation procedure for MCPP. The mixture aqueous solution of MCPP, $[Ru(2,2'\text{-bipy})_3]Cl_2$ and ascorbic acid (ASC) was bubbled with argon gas for 15 min to remove oxygen first and then the commercial LED (λ = 452 ±5 nm) as light source was used for these irradiation experiments.

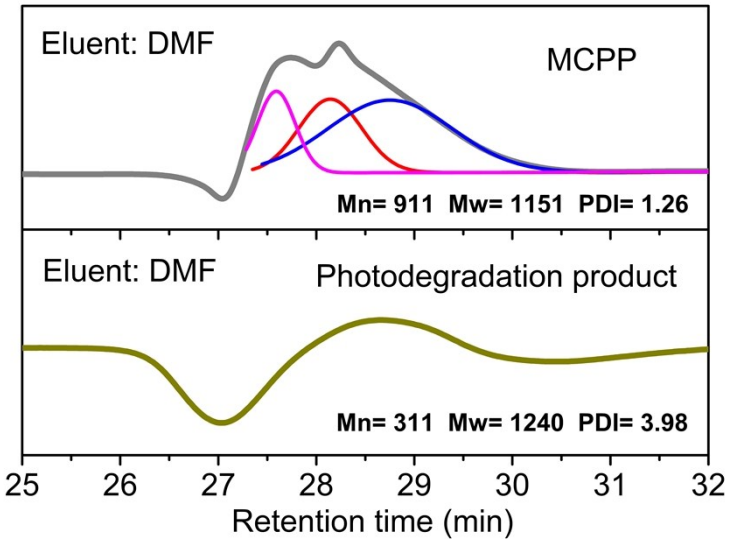


Figure S4. The GPC measurements of MCPP and its photodegradation product when using DMF as eluent.

General procedure for ion exchange. Bis(trifluoromethane)sulfonimide lithium salt (Tf_2NLi) was added into the aqueous solution of photodegradation products. A dark red precipitate was observed. The obtained precipitate was dissolved in CH_3CN and precipitated in water again followed by vacuum for 12 h at 50 °C.

A solution of MCPP and silver trifluoromethanesulfonate (AgOTf) (1:1, molar ratio of I^- and OTf^-) in methanol was stirred for 3 hours at room temperature. Then the reaction mixture was centrifuged and the liquid phase was dried under reduced pressure. Finally, MCPP (OTf^-) was obtained.

Table S2. Visible light degradation of MCPP with different conditions [a]

Entry[a]	C_{Ru} ($umol \cdot L^{-1}$)	C_{ASC} ($mol \cdot L^{-1}$)	(n_{ASC}/n_{C-O})[b]	t (h)	*I* ($mW\ cm^{-2}$)	DE%
1	45	0.06	1	12	30	57
2	45	0.18	3	12	30	74
3	45	0.31	5	12	30	80
4	45	0.62	10	12	30	95
5	45	0.62	10	0.3	30	39
6	45	0.62	10	1	30	60
7	45	0.62	10	6	30	82
8	45	0.62	10	12	15	78
9	4.5	0.62	10	12	30	85

[a] The concentration of MCPP used is 24 mg mL^{-1}.

[b] $n_{C-O} = \frac{m}{M_1+M_2} \times 2$

(m: the mass of MCPP; M_1 and M_2: Molecular weight of **1** and **2**)

Synthesis of $MCPP_{4K}$(I). $MCPP_{4K}$(I) was synthesized as same as that of MCPP described above as orange red solid.

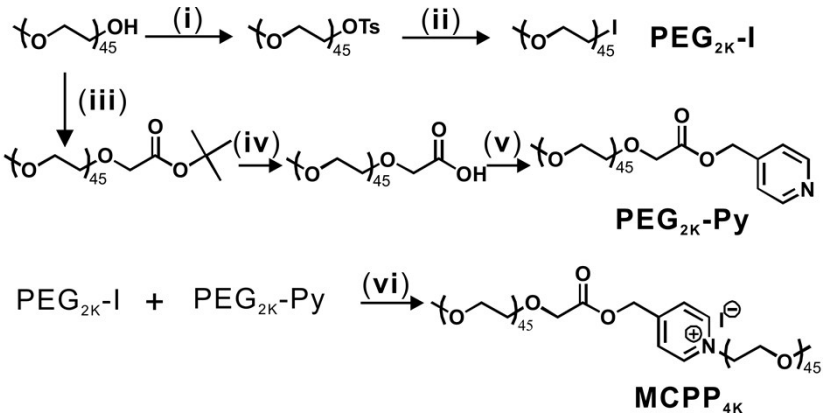


Figure S5. Synthesis and photodegradation of $MCPP_{4K}$. (i) pTsCl, TEA, CH_2Cl_2; (ii) NaI, acetone, 60 °C reflux, 24 h; (iii) Ar, NaOH, CH_2Cl_2, 60 h; (iv) pH=1, 0 °C, 30 min, 60 °C 4h; (v) 4-Pyridinemethanol, EDC, DMAP, CH_2Cl_2, rt, 48 h; (vi) CH_3CN, 82 °C, 48 h.

Tosylation of methoxy-terminated poly(ethylene glycol). A solution of PEG_{2K} (10 g, 5 mmol) and triethylamine (15 ml, 110 mmol) in dried CH_2Cl_2 (40 ml) was cooled in an ice bath. A solution of p-toluenesulfonyl chloride (p-TsCl) (9.53 g, 50 mmol) in 50ml of dried CH_2Cl_2 was added dropwise. After 1 h of stirring in an ice bath, the solution was allowed to stir for another 24 h at room temperature. The mixture was sequentially washed with saturated $NaHCO_3$ and brine. The organic phase was dried over anhydrous $MgSO_4$ and filtered. The filtrate was concentrated via rotary evaporation and residue was precipitated into Et_2O. The precipitate was isolated and vacuum for 12 h at room temperature to afford PEG_{2K}-OTs as soil gray solid (8.03 g, yield 80%).

Iodination of PEG_{2K}-OTs. The PEG_{2K}-OTs (5.00 g, 2.3 mmol) was dissolved in acetone (50 mL) and added to a 100 mL round-bottom flask equipped with a magnetic stir bar. With the solution stirring, a solution of NaI (3.46 g, 23 mmol) in 30 ml of acetone was added slowly in dark and heated to reflux for 24 h. A white solid eventually settled down in the flask and removed by filter. After the filtrate was evaporated to remove acetone, CH_2Cl_2 (60 mL) and deionized water (40 mL) were added to the residue left behind in the flask. The mixture was stirred for 30 min at room temperature. The organic and aqueous phases were separated, and the organic phase was sequentially extracted with 5% $Na_2S_2O_3$ solution, saturated $NaHCO_3$

solution and DI water. Then the organic phase was dried over anhydrous $MgSO_4$ and filtered. After vacuum evaporation, the viscous liquid was further precipitated into Et_2O to afford PEG_{2K}-I as white solid (3.91 g, yield 80%).

Synthesis of PEG_{2K}-Py. Methoxy-terminated poly(ethylene glycol) (10 g, 5 mmol) was dissolved in dry CH_2Cl_2 (60 ml) under nitrogen environment and cooled in an ice bath. Sodium hydroxide solid (1.3 g, 30 mmol) was added and stirred 1.5 h at 0 ^oC. Then tert-butyl bromoacetate (8 g, 40 mmol) was added and the reaction was maintained at 0 ^oC for 1 h, followed with stirring for another 60 h at room temperature. The reaction was filtered and filtrate was evaporated under vacuum. The residue left behind in the flask was precipitated into Et_2O and obtained white solid (13.2 g). The white solid above was dissolved in water (70 ml) and the pH was adjusted to 1 at 0 ^oC with hydrochloric acid. After maintained 0 ^oC for 30 min, the reaction was stirred for an additional 6 h at 60 ^oC. The reaction mixture was evaporated under vacuum and precipitated into Et_2O. Carboxyl-Monomethoxy poly(ethylene glycol) was obtained as claybank solid.

Esterification of carboxyl-monomethoxy poly(ethylene glycol). Carboxyl-Monomethoxy poly(ethylene glycol) (5 g, 2.41 mmol), 4-Pyridinemethanol (1.33 g, 12.05 mmol) and DMAP (0.8 g, 3.01 mmol) was dissolved in 100 mL of CH_2Cl_2 at 0 ^oC. Then EDC (4.7 g, 24.1 mmol) was added in batches. The reaction was allowed to stir at room temperature for 48 h. Then the reaction was washed with 5% HCl, saturated $NaHCO_3$ solution, brine and dried over anhydrous $MgSO_4$. After vacuum evaporation. The residue left behind in the flask was precipitated into Et_2O to obtain PEG_{2K}-Py as white solid (3.57 g, yield 70%).

Characterization of Single molecule force spectroscopy. The samples were prepared by dissolving polymers in water for ~24 h to a concentration of 0.01 $g \cdot mL^{-1}$. A drop of the aqueous solution (~10 μL) was deposited on a clean glass slide for 30 min, followed by thorough rinse with DI water. After that, the sample was mounted in the

AFM (Nanowizard II from JPK Instruments and MFP-3D from Asylum Research). Prior to the measurements, a drop of water was introduced between the V-shaped Si3N4 AFM cantilever (Bruker Corp.) and the sample. During the force measurements, the data was collected at the same time and converted to F−E curves later. The spring constant of the AFM cantilever was measured by the thermoexcitation method, ranging from 30 to 50 pN/nm. The stretching velocity applied is 2.0 μm/s.

Single-Channel Recording and Data Analysis. A bilayer of 2-diphytanoylphosphatidylcholine was formed over a 120− 160 μm orifice in a Teflon septum that divided a planar bilayer chamber into cis and trans compartments. The formation of the bilayer was achieved using the Montal−Mueller method[3]. Solutions contained KCl at a desired concentration and was buffered with 10 mM Tris (pH 7.2). α-HL protein and PEG samples added to the cis compartment, which was connected to a "ground". The final concentration of the α-HL proteins used for the single-channel insertion was 0.05−0.2 ng/mL. Currents were recorded with a patch clamp amplifier (Axopatch 200B, Molecular Devices, Sunnyvale, CA), filtered with a built-in four-pole Bessel filter at 5 kHz, sampled at 20 kHz by a computer equipped with a Digidata 1440 A/D converter (Molecular Devices), and acquired with Clampex 10.3 software (Molecular Devices). Single-channel event amplitude and duration were analyzed using Clampfit 10.3 (Molecular Devices) software. Mean dwell time values were obtained from the dwell histograms after the peaks were fitted to single exponential functions. The standard deviation of open pore current was obtained from single channel current baseline histograms by fitting the distributions to Gaussian functions. The values of mean signal amplitude and I/I_0 were obtained from signal amplitude and I/I_0 histograms by fitting the distributions to Gaussian functions.

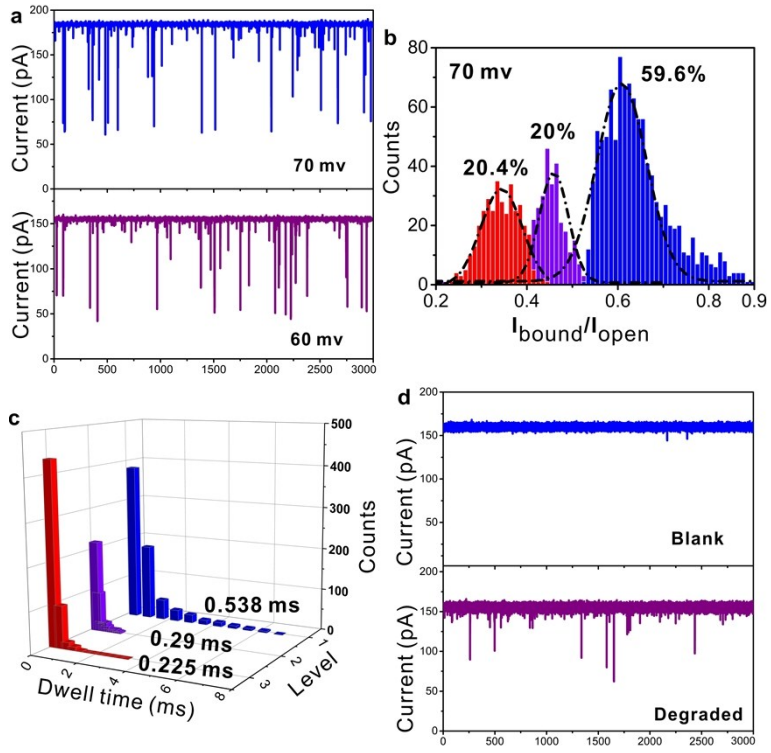


Figure S6. (a) Representative single-channel current traces of MCPP and degradation products passing the α-HL pore at different applied bias voltages in aqueous solution of 3 M KCl and 10 mM Tris (pH=7.2). (b and c) Histogram of bound currents and dwell times for MCPP at different applied voltages. (d) Representative single-channel current traces of blank and degradation products.

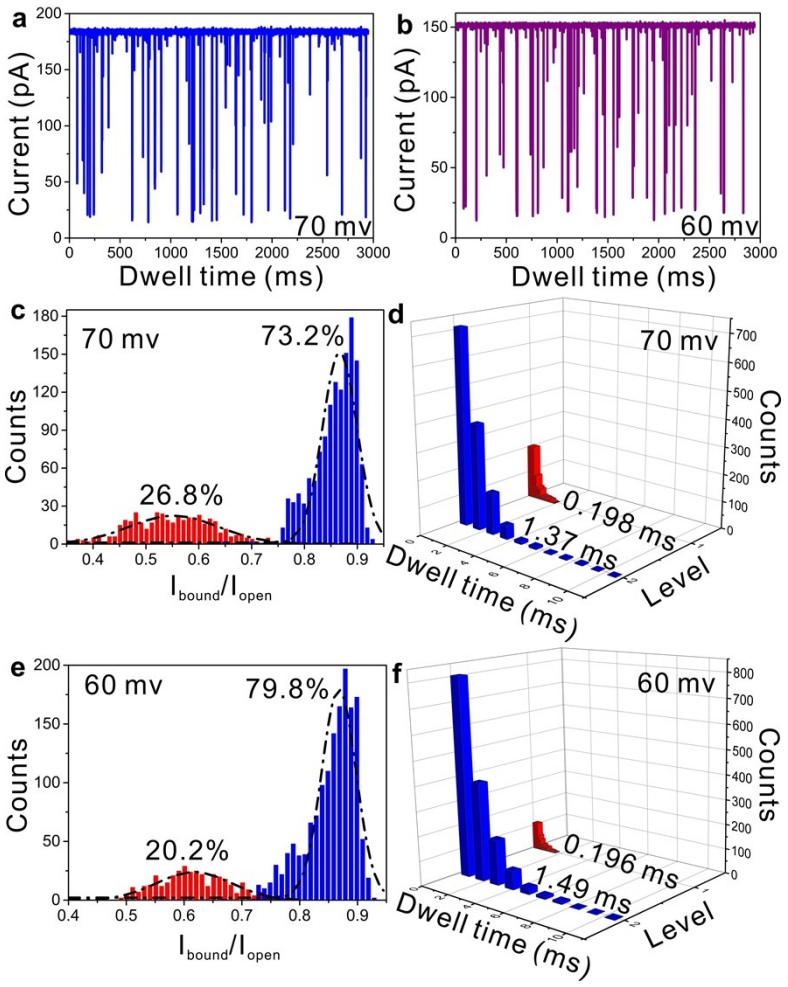


Figure S7. (a and b) Representative single-channel current traces of pure PEG passing the α-HL pore at different applied voltages in aqueous solution of xxx M KCl. Histogram of bound currents and dwell times for pure PEG at (c and d) 70 mV and (e and f) 60 mV, respectively.

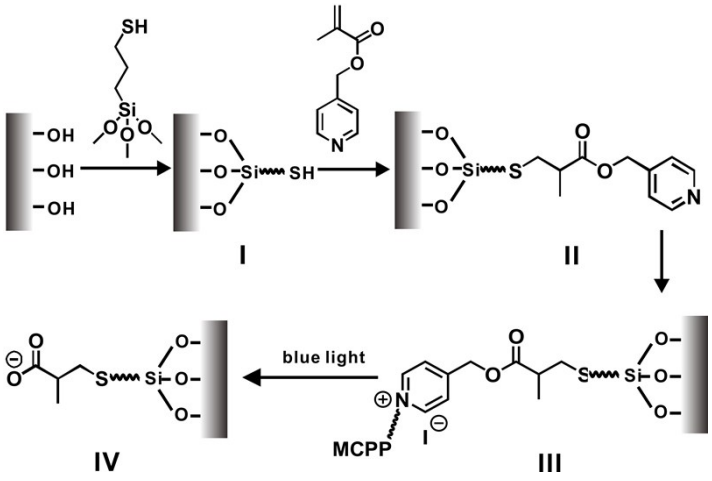


Figure S8. Modification and photodegradation of MCPP on glass slides.

Modification and photodegradation of MCPP modified Surfaces. The cleaned substrates (quartz or glass wafers) were immersed into a 3-Mercaptopropyl trimethoxysilane solution in dichloromethane (v/v= 1/500) for about 5 h at room temperature. After being rinsed with dichloromethane, methanol, respectively, and dried with air flow, the thiolated quartz or glass substrates (**I**) were obtained. Sequentially, the substrate **I** was immersed into a mixed methanol solution of 4-picolyl methacrylate ester[4] and eosin Y, and then was exposed to green LED light (515 nm, 13 $mW \cdot cm^{-2}$) for 20 min. The substrate (**II**) was prepared after being rinsed by extensive methanol and dried with air flow. Next, the substrate **II** was immersed into the acetonitrile solution mixed with typical monomers (i.e., **1** and **2**) at 82 ^{o}C for 48 h under Ar. The MCPP immobilized surface (**III**) was obtained by washing with water, methanol, respectively, and drying. The photodegradation of MCPP immobilized surface was conducted by irradiating the substrate **III** with blue light (452 nm, 30 $mW \cdot cm^{-2}$) in an aqueous solution of $[Ru(bpy)_3]^{2+}{}_2Cl^-$ and ascorbic acid.

In vitro cytotoxicity analysis. Human bone marrow mesenchymalstem cells (BMSCs, isolated from normal adult human bone marrow) were seeded at 3×10^3 per well in 96-well plate for 24h before treatment. The cells were then exposed to MCPP and its degradation products with different concentration ranging from 0.1 to 500 μg mL-1 for 24 h, 48 h and 72 h. Cell viability was measured by using the 3-(4,5-dimethylthiazole-2-yl)-2,5-diphenyl tetrazolium bromide (MTT, Sigma-Aldrich, USA) according to the manufacture's protocol. The absorbance of the wells was read at 570 nm by using Varioskan Flash multimode reader (Thermo Fisher Scientific, USA).

In vitro analysis of cell adhesion. The bare glass slides, glass slides covered by MCPP before and after UV irradiation were placed in individual wells of a 6-well plate. The slides were washed three times with 75% ethanol followed by three washes with PBS. Then human bone marrow mesenchymalstem cells (BMSCs, isolated from normal adult human bone marrow) were added to each well at a density of $2x10^5$/well.

The samples were cultured in Alpha Minimum Essential Medium (α-MEM) supplemented with 10% FBS, 100 units ml^{-1} penicillin and 100 μg ml^{-1} streptomycin at 37 °C in a humidified atmosphere of 5% CO_2 for 24 hours. After that, the samples were collected and further cultured in fresh α-MEM with no cells for another 24, 48 and 72 hours.

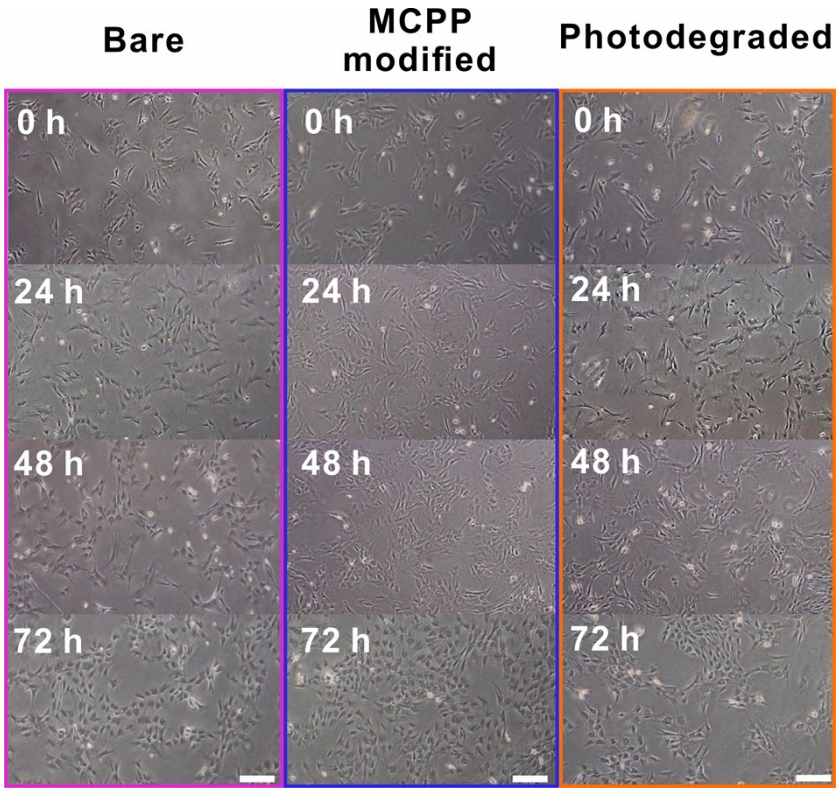
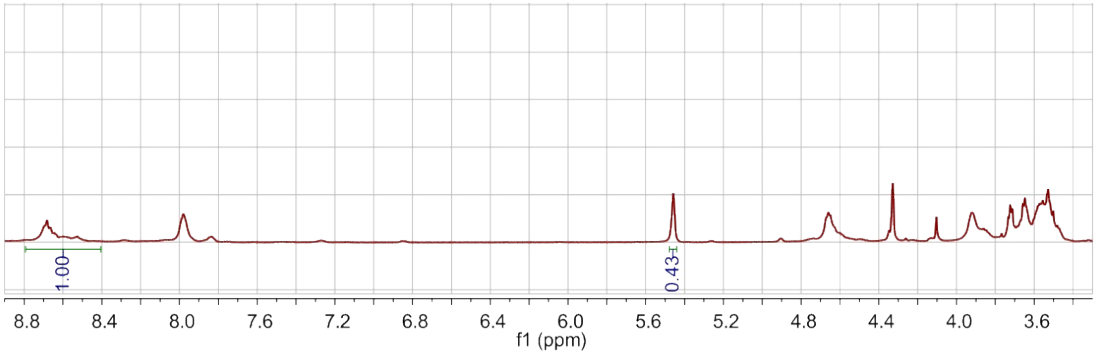


Figure S9. Optical images of BMSCs cells on bare, MCPP modified and photodegraded substrates with different incubation times.

^{1}H NMR spectra of monomers in Figure S1, MCPP and photodegradation products in Table S2

Entry 1



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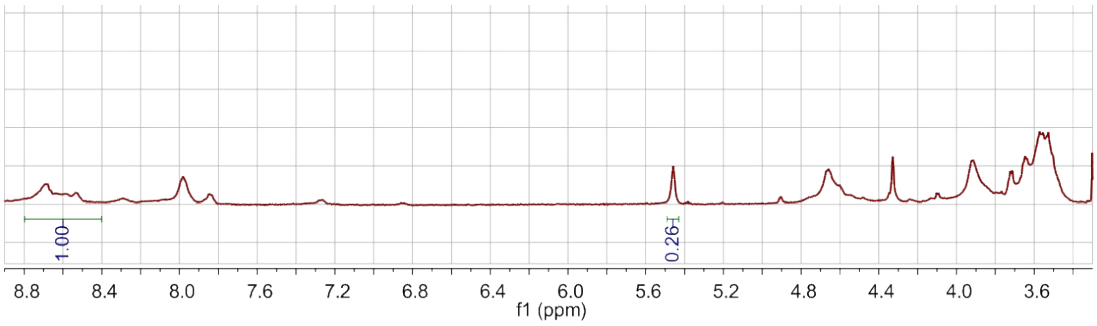

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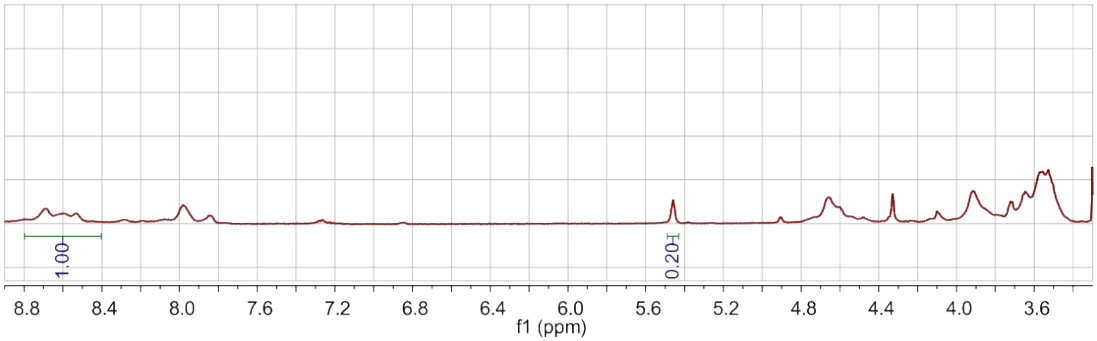

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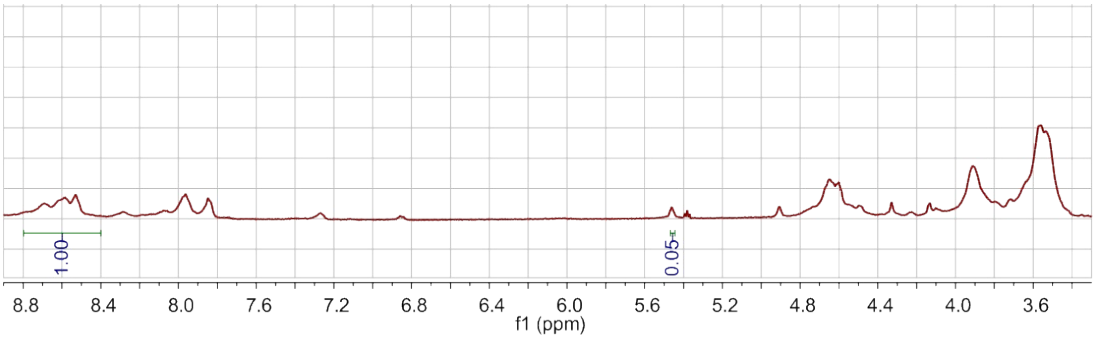

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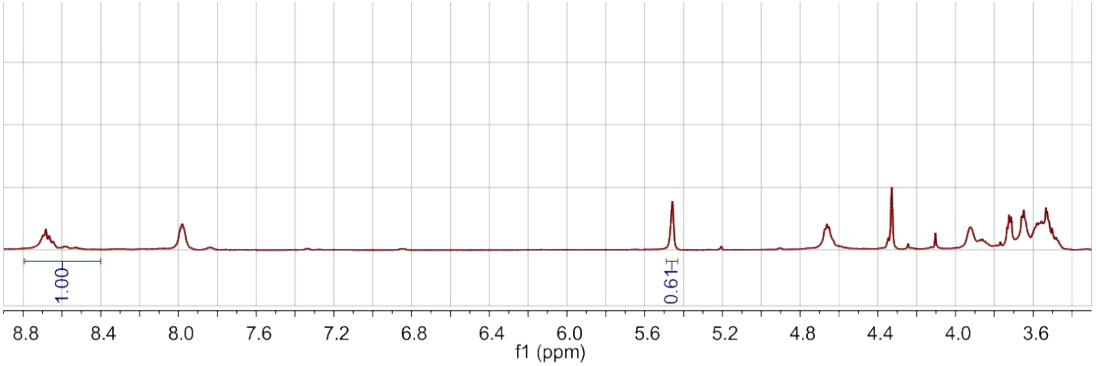

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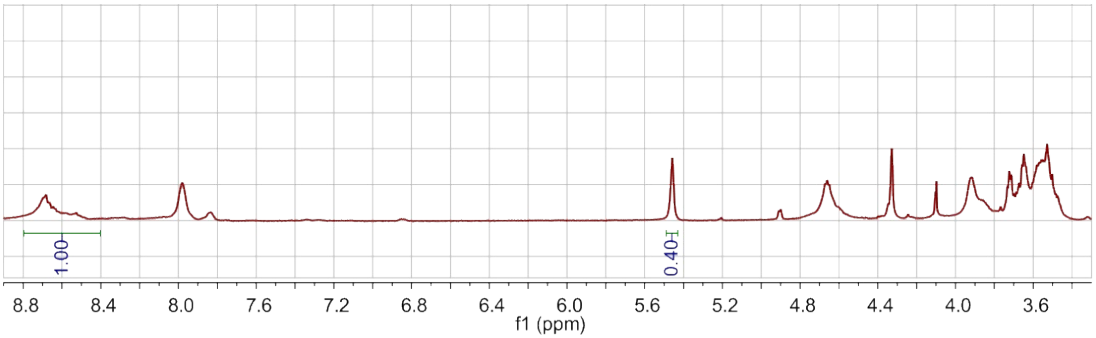

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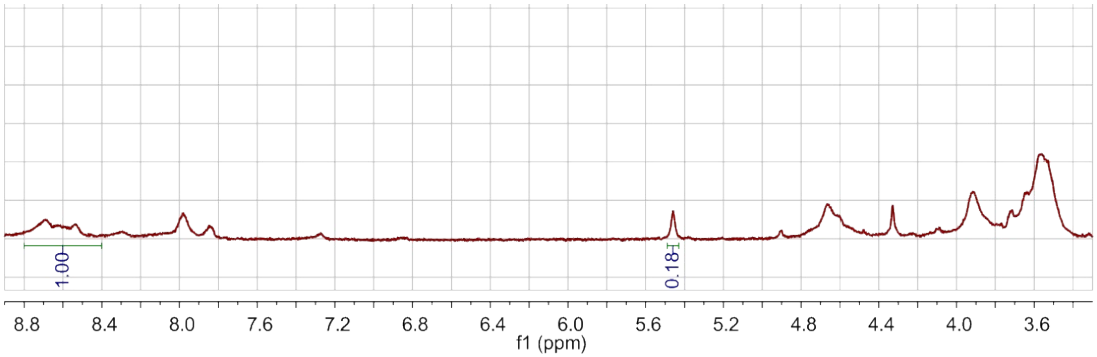

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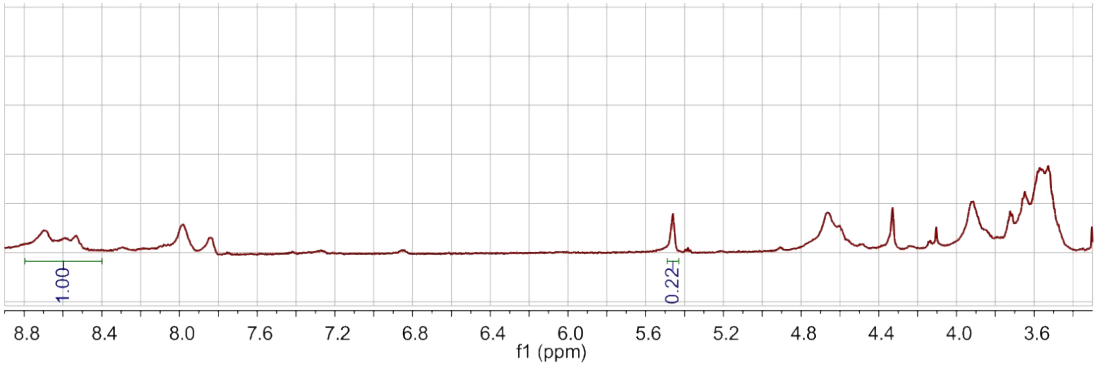

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