

Electronic Supplementary Information for:

Tunable thermo-, pH- and light-responsive copolymer micelles

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Scheme S1 Synthesis of PDMAEMA-*b*-PAP block copolymer.

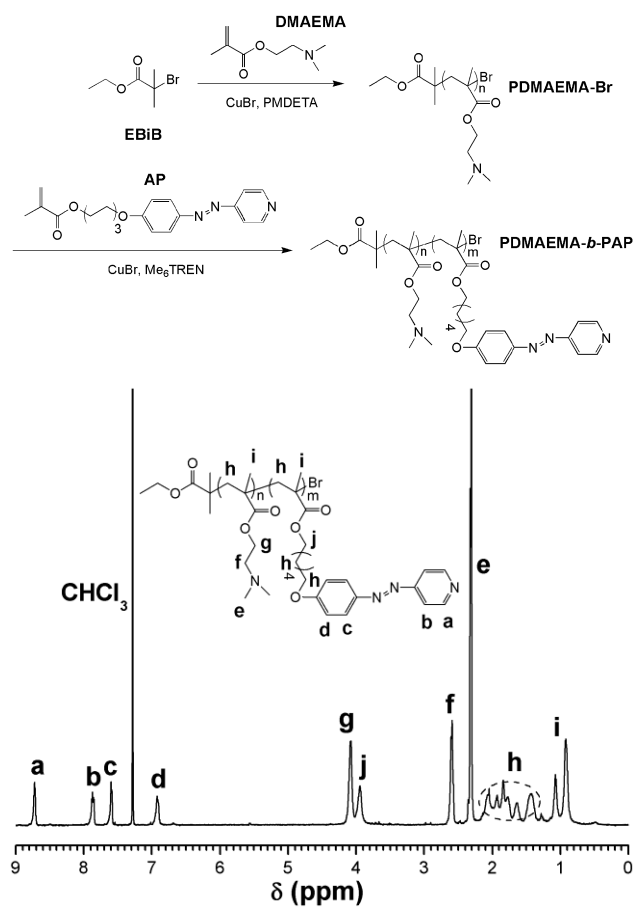


Fig. S1 ¹H NMR spectrum of PDMAEMA-*b*-PAP block copolymer in CDCl₃.

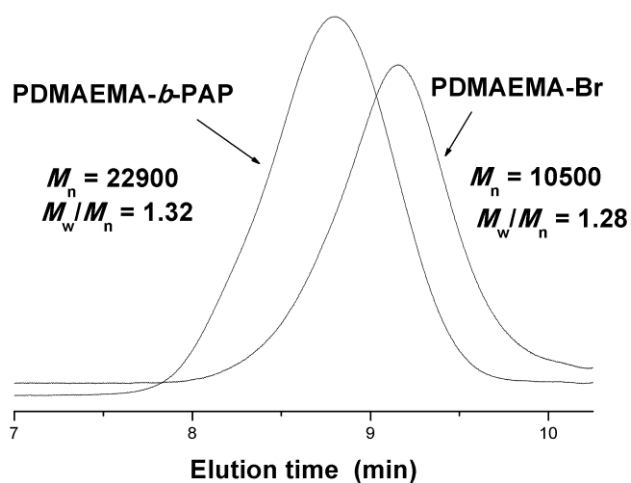


Fig. S2 GPC traces of polymers of PDMAEMA-Br and PDMAEMA-*b*-PAP in DMF.

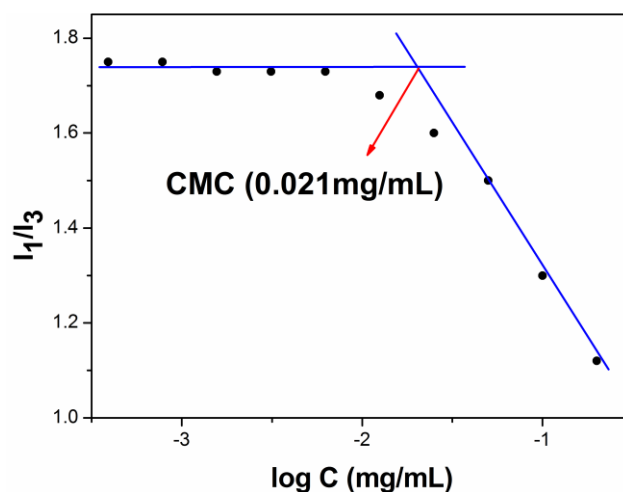


Fig. S3 Determination of CMC for the block copolymer PDMAEMA-*b*-PAP using the fluorescent method with pyrene as a probe, the CMC is 0.021 mg/mL.

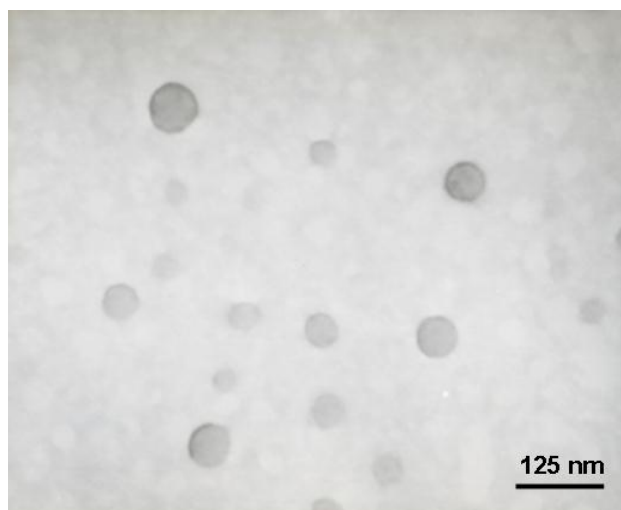


Fig. S4 TEM image of PDMAEMA-*b*-PAP micelles (25°C and pH 7).

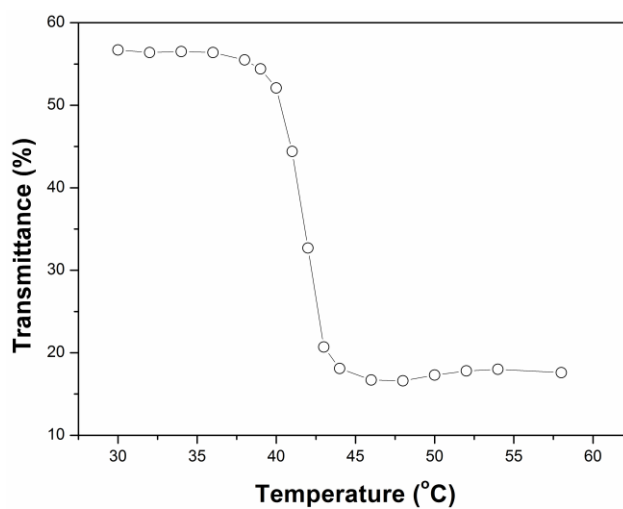


Fig. S5 Temperature dependence of transmittance for PDMAEMA-*b*-PAP micelle solution (2

mg/mL).

Experimental Section

Materials

Ethyl 2-bromoisobutyrate (Aldrich, USA), *N,N,N',N'',N''*-pentamethyldiethylenetriamine (PMDETA; Acros Organic, USA), tris[2-(dimethylamino)-ethyl]amine (Me₆TREN; Aldrich, USA), and Nile red (Acros Organic, USA) were used as received. The azopyridine monomer, 6-[[4-(4-pyridylazo)phenoxy] hexyl methacrylate} (AP), was synthesized according to the literatures.^{1, 2} 2-(*N,N*-dimethylamino)ethyl methacrylate (DMAEMA; Acros Organic, USA) was dried over CaH₂ and distilled under reduced pressure. CuBr was purified via stirring in acetic acid and washing with ethanol and then dried *in vacuo*. DMF was dried over CaH₂ and distilled under reduced pressure. *n*-Hexane and THF were used as received.

Characterization

¹H NMR spectrum was obtained from a Bruker AV 400 NMR spectrometer at ambient temperature with CDCl₃ as the solvent. The chemical shifts were relative to tetramethylsilane.

DMF GPC. GPC analysis was carried out with a HLC-8320 (Tosoh, Japan) analysis system with two columns (TSK gel super AWM-H×2, R0091+R0093), using DMF with 10 mM LiBr as eluents at a flow rate of 0.6 mL min⁻¹ at 40°C. PMMA calibration kit was used as the calibration standard.

Transmission electron microscopy (TEM) images were obtained using an H-800 (Hitachi, Japan) TEM at an accelerating voltage of 120 kV. A small drop from the aqueous copolymer solutions was deposited onto carbon-coated copper TEM grid. The excess of solution was wiped off with a filter paper, and the grid was dried under ambient atmosphere. The samples were stained by 1%

phosphotungstic acid.

Critical micelle concentration (CMC) was determined using pyrene as a fluorescence probe. 10 μ L of pyrene (0.45 mg/mL) in acetone was added to a series of 10.0 mL volumetric flasks. After the acetone evaporated, a measured amount of PDMAEMA-*b*-PAP solution was added to each flask, then added followed by doubly distilled water. The flasks were kept for 12 h to equilibrate the pyrene and the micelles. The fluorescence spectra were recorded using a Hitachi F2500 luminescence spectrometer (Hitachi, Ltd.) with an excitation wavelength of 334 nm. The emission wavelengths at 371 nm (I_1) and 383 nm (I_3) were monitored. The CMC value was chosen as the concentration when pyrene exhibited an apparent decrease in the I_1/I_3 ratio with an increasing concentration of the copolymer, indicating that the aggregation of the copolymer occurred.

The optical transmittances of the copolymer micelles aqueous solution at various temperatures were measured at a wavelength of 500 nm using a UV-visible spectrophotometer (Lambda 35, PerkinElmer). The temperature of the sample cell was thermostatically controlled using an external superconstant temperature bath. The solution was equilibrated for 10 min at each measuring temperature. The LCST value of the micelle solution was defined as the temperature producing a 50% decrease in optical transmittance.

DLS studies were conducted using a Zetasizer Nano ZS90 instrument (Malvern Instruments) equipped with a multipurpose autotitrator (MPT-2) at a fixed scattering angle of 90°. The data were processed by cumulants analysis of the experimental correlation function. The micellar radiuses were calculated from the computed diffusion coefficient using the Stokes-Einstein equation.

UV-Vis absorption studies were carried out using a U-3310 spectrophotometer (Hitachi, Japan)

equipped with a temperature controller (0.1°C accuracy).

Fluorescence spectra were recorded using an F-2500 spectrometer (Hitachi, Japan) with a xenon lamp source. Fluorescence scans were performed at room temperature in the range of 500-800 nm, using a speed of 1500 nm min⁻¹, an excitation wavelength of 500 nm, which is at the maximum absorption peak for Nile red.

A UV LED irradiator (UVATA, λ_0 = 365 nm) and a Vis LED irradiator (CCS, λ_0 = 530 nm) were used to induce the photoisomerization of azopyridine moieties.

Synthesis of PDMAEMA-Br by ATRP

The synthesis procedure was as follows. A dried Schlenk flask with a magnetic stirrer was charged with CuBr (85 mg, 0.6 mmol), ethyl 2-bromoisobutyrate (EBiB, 78 mg, 0.4 mmol), DMAEMA (6 g, 38 mmol), and dried DMF (6 mL). The flask was degassed with three freeze-evacuate-thaw cycles. PMDETA (250 μ L, 1.2 mmol) was deoxygenated by bubbling dry argon before injection into the reaction system by syringe. The molar ratio of [DMAEMA]: [EBiB]: [CuBr]: [PMDETA] was 95: 1: 1.5: 3. The polymerization reaction was performed at 50°C for 5 h. After being cooled to room temperature, the reaction flask was opened to air, and the crude product was diluted with THF and passed through a neutral oxide alumina column to remove the copper catalysts. The polymer was obtained by precipitation in n-hexane and dried *in vacuo* for 48 h.

Synthesis of PDMAEMA-*b*-PAP block copolymer by ATRP

A dried Schlenk flask with a magnetic stirrer was charged with CuBr (17 mg, 0.12 mmol), PDMAEMA-Br (1.26 g, 0.12 mmol), AP (2.3 g, 6.3 mmol), and dried DMF (5 mL). The flask was degassed with three freeze-evacuate-thaw cycles. Me₆TREN (45 μ L, 0.30 mmol) was deoxygenated by bubbling dry argon before injection into the reaction system by syringe. The

molar ratio of [AP]: [PDMAEMA-Br]: [CuBr]: [Me₆TREN] was 52.5: 1: 1: 3. The polymerization reaction was performed at 80°C for 72 h. After being cooled to room temperature, the reaction flask was opened to air, and the crude product was diluted with THF and passed through a neutral oxide alumina column to remove the copper catalysts. The polymer was obtained by precipitation in n-hexane and dried *in vacuo* for 48 h.

Self-assembly of PDMAEMA-*b*-PAP block copolymer to micelles

The following protocol was adopted to self-assemble the block polymer into micelles. PDMAEMA-*b*-PAP copolymer (20 mg) was dissolved into THF (10 mL). Then deionized water (10 mL) was added at a rate of 1 mL h⁻¹ under vigorous stirring. Then the solution was dialyzed against water with a dialysis tube (molecular weight cut-off: 8000-14000) at 25°C. The micelles solutions with different pH values were obtained by adding aqueous HCl or NaOH solutions to the above solutions.

References

1. L. Cui and Y. Zhao, *Chem. Mater.*, 2004, **16**, 2076-2082.
2. M. Millaruelo, L. S. Chinelatto, L. Oriol, M. Pinol, J. L. Serrano and R. M. Tejedor, *Macromol. Chem. Phys.*, 2006, **207**, 2112-2120.