Supplementary Material (ESI) for *Soft Matter*

Supporting information

A schizophrenic gradient copolymer: Switching and reversing poly(2 oxazoline) micelles based on UCST and subtle solvent changes

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Contents:

1. Experimental part

Materials

Solvents were purchased from Biosolve. Acetonitrile was dried over molecular sieves(size 3 Å). 2-Phenyl-2-oxazoline (PhOx; Aldrich) and 2-nonyl-2-oxazoline (NonOx; kindly donated by Henkel) were distilled over barium oxide (BaO) and stored under argon. Methyl tosylate (Aldrich) was distilled without drying agent and stored under argon.

Instrumentation

Polymerizations were carried out in an Emrys Liberator microwave synthesizer (Biotage) utilizing capped reaction vials. These vials were heated to 105 ºC, allowed to cool to room temperature and filled with argon prior to use. All microwave polymerizations were performed with temperature control.

Size exclusion chromatography (SEC) was performed on a Shimadzu system with a SCL-10A system controller, a LC-10AD pump, a RID-10A refractive index detector and PSS gram 30 (pore size 30 Å; bead size 10 µm; 100 – 10,000 Da) and PSS gram 1000 (pore size 1000 Å; bead size 10 µm; 1,000 – 1,000,000 Da) columns in series at 60 °C. A solution of *N,N*-dimethylacetamide (DMAc) containing 2.1 g LiCl/L was used as an eluent at a flow rate of 1 mL/min. The molecular weights were calculated against poly(styrene) (PS) calibration standards.

Gas chromatography (GC) measurements were performed on an Interscience Trace gas chromatograph with a Trace Column RTX-5 connected to a PAL autosampler. For the direct injection of the polymerization mixtures, a special Interscience liner with additional glass wool was used.

The compositions of the polymers were determined using ^{1}H NMR spectroscopy. Spectra were recorded on a Varian Mercury 400 MHz spectrometer in $CDCl_3$. The residual protonated solvent signals were used as reference.

The cloud points were determined by turbidity measurements in a Crystal 16^{TM} by Avantium Technologies. Four blocks of four parallel temperature controlled sample holders are connected to a Julabo FP40 cryostat allowing 16 simultaneous measurements. Turbidity of the solutions was measured by the transmission of a red light through the sample vial as a function of the temperature. Solutions of the polymers were prepared in deionized water

(Laborpure, Behr Labor Technik) and were stirred at room temperature until all polymer was dissolved or dispersed. Two heating/cooling cycles were applied from – 25 °C to 100 °C at 1 °C/min with hold steps of 5 min at the extreme temperatures. The cloud points are given as the 50% transmittance point during the second cooling ramp.

Transmission electron microscopy (TEM) measurements were performed on a FEI Tecnai 20, type Sphera TEM operating at 200 kV (LaB_6 filament). Images were recorded with a bottom mounted 1k × 1k Gatan CCD camera. 200 Mesh carbon coated copper TEM grids were purchased from SPI. Prior to blotting, the grids were made hydrophilic by surface plasma treatment using a Cressington 208 carbon coater operating at 5 mA for 40 seconds. For conventional sample preparation 3 μL aliquots were applied to the grid and subsequently excess liquid was quickly manually blotted away with filter paper. The sample of the micelles at – 20 ºC were prepared on a 200 mesh carbon-coated copper grid that was cooled by placing it on an aluminium plate inserted in a frozen water-ethanol mixture, the aluminium plate was surrounded in a nitrogen atmosphere to avoid water condensation. A droplet from a cooled solution was applied to the cooled 200 mesh carbon-coated copper grid and subsequently any excess liquid was quickly manually blotted away with filter paper.

DLS measurements were performed at an angle of 90º on a Malvern CGS-3 apparatus equipped with a He-Ne laser (632.8 nm). A bath of filtered toluene surrounded the scattering cell, which was controlled at the desired temperature. DLS data were analyzed by the CONTIN method, as described elsewhere (B. J. Berne, R. J. Pecora, *Dynamic Light Scattering*, Wiley, Toronto, **1976**). The CONTIN routine is based on a constraint inverse Laplace transformation of the data and gives access to a size distribution histogram for the aggregates. To calculate the hydrodynamic radii, the Stokes-Einstein equation was applied using the viscosity data for ethanol at different temperatures included in the software.

For the other water-ethanol solvent mixtures, the viscosity was determined at different temperatures using a AMVn automated viscosimeter from Anton Paar. The dynamic viscosities were determined at an angle of 50º utilizing a 1.6 measuring system set and are listed below:

Ethanol-water 80/20 wt%: 25 ºC: 1.9426 mPa × s.

Ethanol-water 80/20 wt%: 40 ºC: 1.1790 mPa × s.

Ethanol-water 60/40 wt%: 50 ºC: 1.1140 mPa × s.

Ethanol-water 60/40 wt%: 70 ºC: 0.7444 mPa × s.

General polymerization procedure

For each polymerization, the polymerization mixture was automatically prepared using an automated synthesis robot (R. Hoogenboom, F. Wiesbrock, M. A. M. Leenen, M. A. R. Meier, U. S. Schubert, *J. Comb. Chem* **2005**, *7*, 10). The polymerization mixtures contain the monomers PhOx and NonOx in the desired ratio with a total monomer concentration of 4 M, acetonitrile and methyl tosylate as initiator with a monomer to initiator ratio of 100. The polymerization mixtures were heated for 45 minutes in the microwave synthesizer at 140 ºC. After microwave heating, the polymerization mixture was cooled to 38 ºC and quenched by the addition of 50 µL water. The polymers were purified by drying overnight under reduced pressure to remove the solvent and minor amounts of residual monomer. The polymers were characterized by ^{1}H NMR spectroscopy, SEC and turbidimetry.

For the kinetic investigation, separate polymerizations were stopped after different predefined reaction times by the addition of water. The monomer conversions were determined by GC.

2. Monomer distribution for PNonOx$_{20}$-*stat*-PPhOx$_{80}$

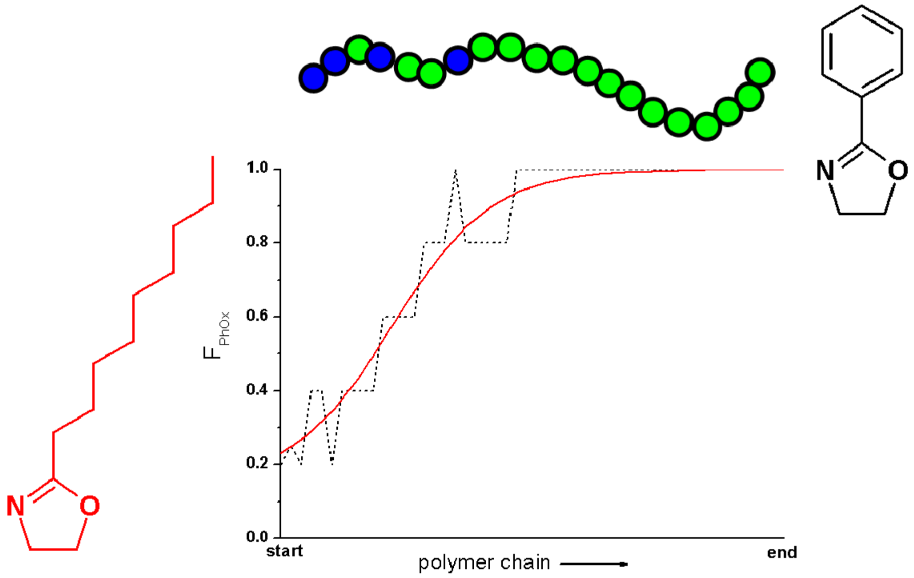

Figure S1. Monomer distribution calculated from the kinetic plot of the copolymerization (Figure 1 in the manuscript) for the statistical copolymerization of NonOx and PhOx in acetonitrile at 140 ºC using methyl tosylate as initiator and [NonOx]:[PhOx]:[MeOTs] = 20:80:1. From the kinetic plot, the monomer sequence was determined by averaging the composition of every five sequential monomers (dotted line). The solid line is a fit to the data showing the average monomer distribution along the polymer chain.

3. Transmittance *versus* temperature plots for the UCST transitions

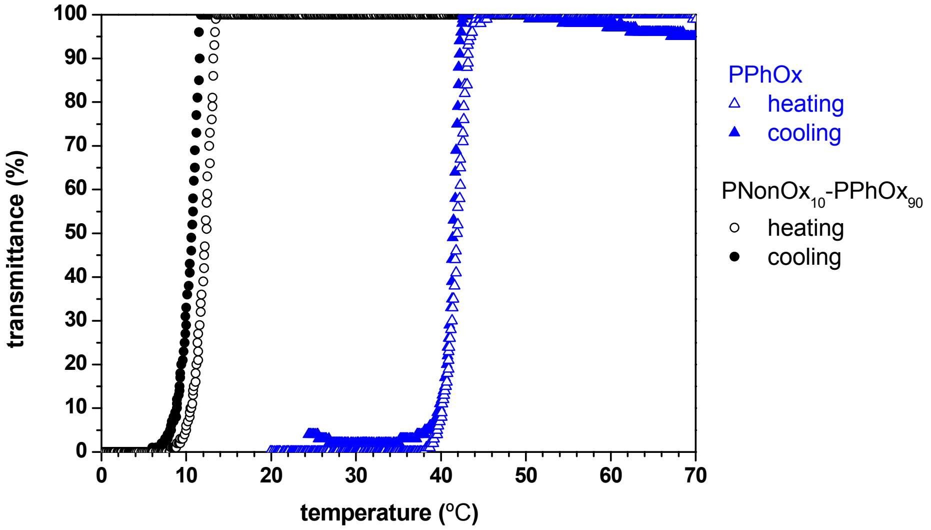

Figure S2. Transmittance *versus* temperature plots in ethanol.

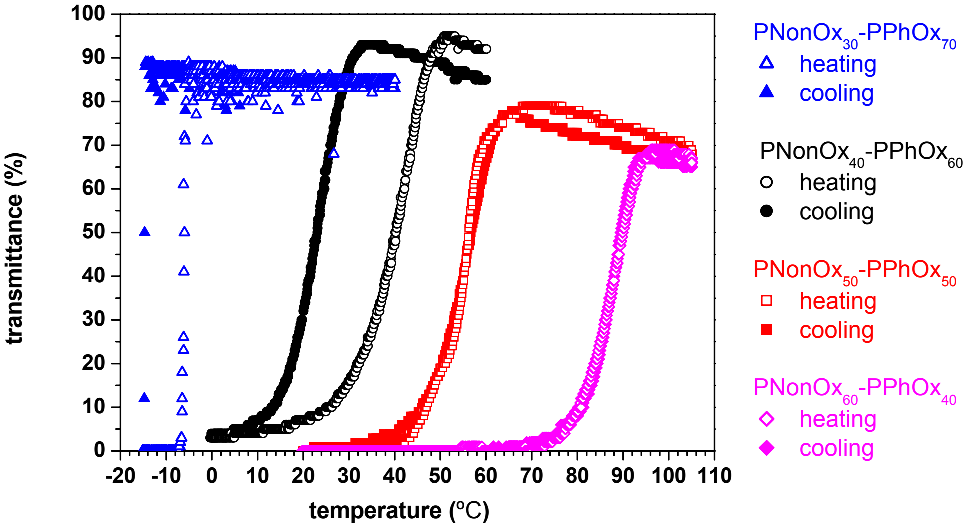

Figure S3. Transmittance *versus* temperature plots in ethanol-water 80/20 wt%.

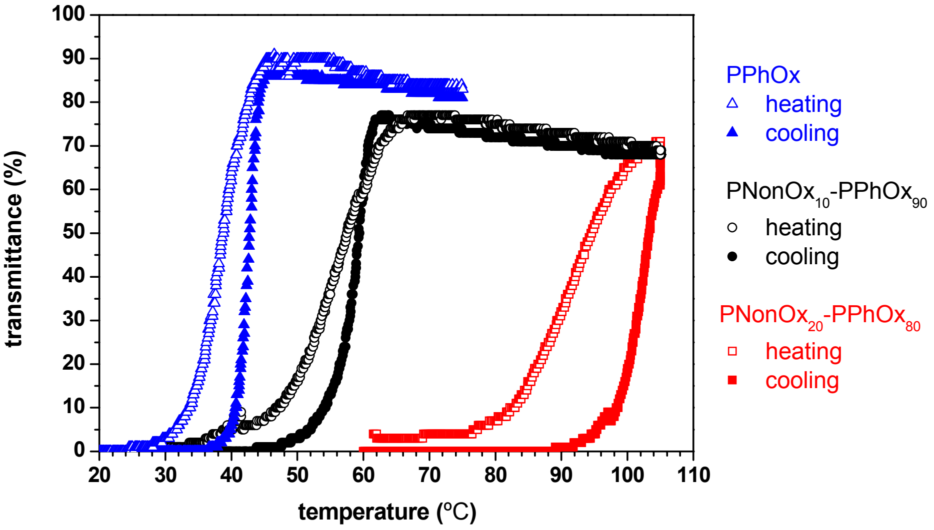

Figure S4. Transmittance *versus* temperature plots in ethanol-water 60/40 wt%.

4. CONTIN plots obtained by dynamic light scattering

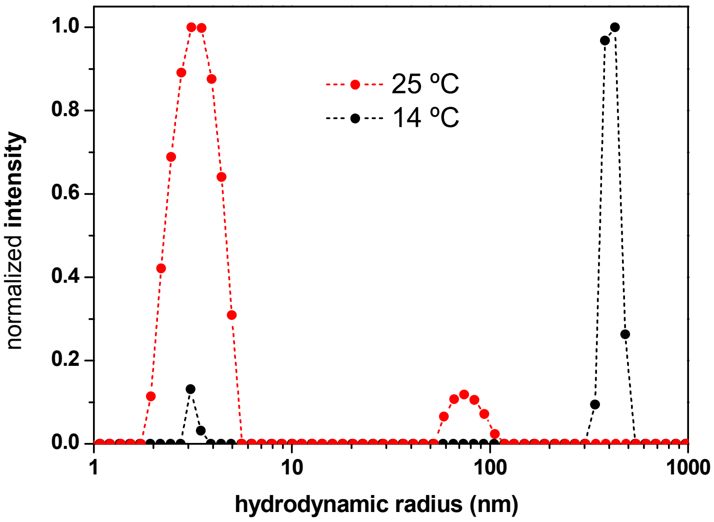

Figure S5. CONTIN plots of PNonOx$_{90}$-*stat*-PPhOx$_{10}$ in ethanol demonstrating the presence of mainly individual chains at 25 ºC and large aggregates at 14 ºC, which is just above the

UCST transition indicating that most likely swollen aggregates are formed. Unfortunately it was not possible to further decrease the temperature with the used DLS apparatus.

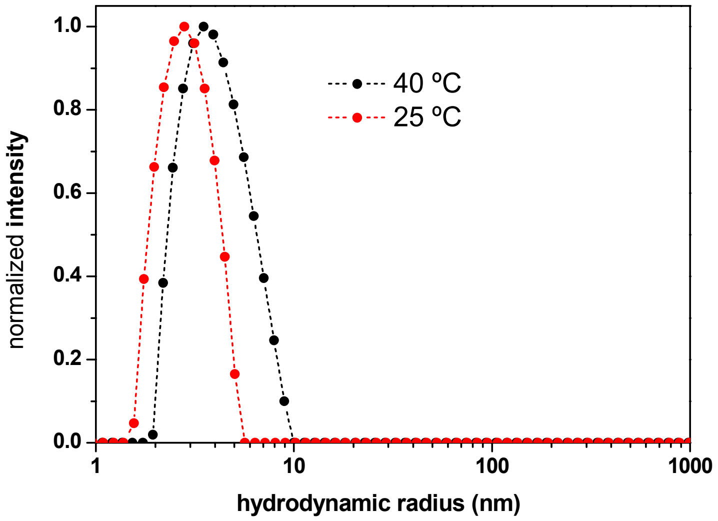

Figure S6. CONTIN plots of PNonOx$_{90}$-*stat*-PPhOx$_{10}$ in ethanol-water 80/20 wt% demonstrating the presence of individual chains at both 25 °C and 40 °C. The hydrodynamic radius is slightly larger at 40 °C due to swelling of the polymer coil.

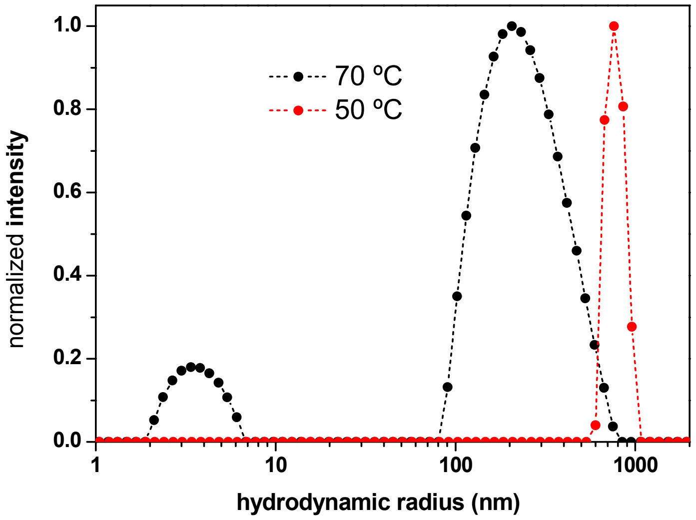

Figure S7. CONTIN plots of PNonOx$_{90}$-*stat*-PPhOx$_{10}$ in ethanol-water 60/40 wt% demonstrating the presence of individual chains and aggregates at 70 ºC. It should be noted that only a minor fraction of aggregates is present, which causes a large scattering intensity due to their size. At 50 ºC only self-assembled structures are present that are most likely swollen aggregates since they were measured just below the cloud point.

5. ^{1}H NMR spectra of micellar solutions of PNonOx$_{10}$-*stat*-PPhOx$_{90}$

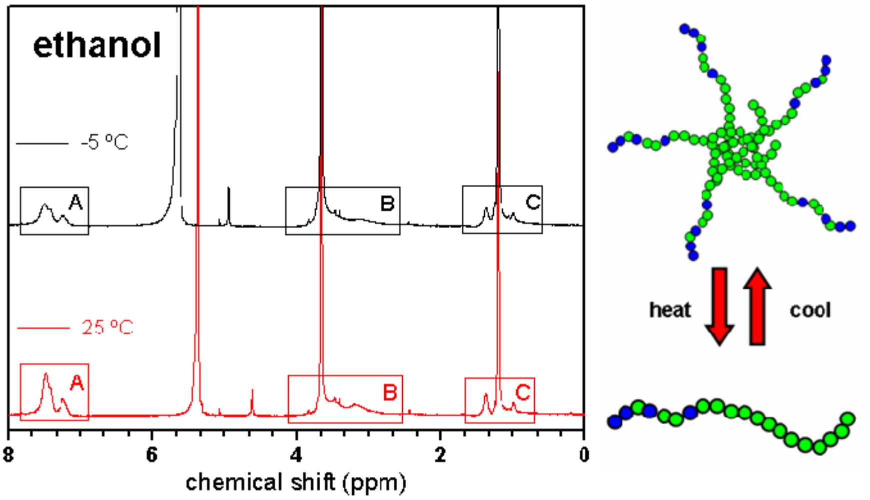

Figure S8. ^{1}H NMR spectra of PNonOx$_{10}$-*stat*-PPhOx$_{90}$ recorded in ethanol-*d6* at 25 °C (bottom) and –5 °C (top). A schematic representation of the organization of the polymer is depicted on the right.

Region A includes the aromatic signals of the PPhOx, region B includes the polymer backbone signals together with an ethanol signal and region C includes the aliphatic PNonOx side chain signals together with an ethanol signal. The ratio of the regions A:B:C in ethanol-*d6* is 6.7:18:10 at 25 °C and 3.3:16.5:10 at –5 °C clearly indicating that PPhOx precipitates upon cooling. At 25 °C the ratio of the NonOx:PhOx ratio was determined to be 1:8 (from the integrals of the terminal CH_3 of PNonOx at 0.9 ppm and the aromatic protons of PPhOx), which is close to the desired composition indicating that the polymer is molecularly dissolved at 25 °C. Unfortunately, this ratio cannot be determined at –5 °C due to broadening and extensive overlap of the signals. Based on these evaluations, it can be concluded that PNonOx$_{10}$-*stat*-PPhOx$_{90}$ is molecularly dissolved in ethanol-*d6* at 25 °C and it self-assembles into micelles at –5 °C due to collapse of the PPhOx part, which is schematically depicted on the right of Figure S2.

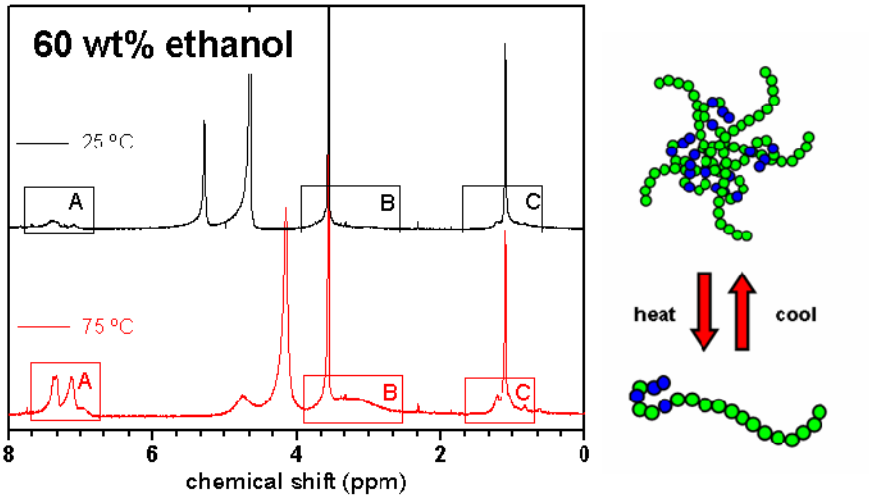

Figure S9. ^{1}H NMR spectra of PNonOx$_{10}$-*stat*-PPhOx$_{90}$ recorded in ethanol-*d6*-D_2O 60/40 wt% at 75 ºC (bottom) and 25 ºC (top). A schematic representation of the organization of the polymer is depicted on the right.

The ratio of the regions A:B:C in ethanol-*d6*-D_2O 60/40 wt% is 10:18:10 at 75 ºC and 3:13:10 indicating that both PNonOx and PPhOx partially precipitate upon cooling. At 75 ºC the NonOx:PhOx ratio was determined to be 1:60 (from the integrals of the terminal CH_3 of PNonOx at 0.9 ppm and the aromatic protons of PPhOx) demonstrating that PNonOx is partially precipitated at 75 ºC. This means that the collapsed PNonOx is solubilized by the large PPhOx part in the copolymer. The NonOx:PhOx ratio cannot be determined at 25 ºC due to broadening and overlap of the signals. Nonetheless, all polymer signals decreased upon cooling indicating the formation of micellar aggregates of almost fully collapsed polymer chains with PNonOx in the inside and PPhOx at the outside due to initial collapse of the PNonOx (depicted on the right of Figure S4).