Supporting Information

Tunable Friction Through Stimuli Responsive Hybrid Carbon Microspheres

Shreyas Oak[1], Leila Pashazanusi[1], Sultan B. Sengel[2], Marzhana Omarova[1], Jamie L. Hemstock[1], Wei He[4], Jibao He[1], Vijay John[1], Nurettin Sahiner[2,3], Noshir S. Pesika[1]*

[1]*Department of Chemical and Biomolecular Engineering, Tulane University, New Orleans, LA 70118, USA*
[2]*Department of Chemistry & Nanoscience and Technology Research and Application Center, Canakkale Onsekiz Mart University Terzioglu Campus, 17100, Canakkale, Turkey.*
[3]*Department of Ophthalmology, Morsani School of Medicine, University of South Florida, Tampa, FL 33612, USA.*
[4]*Shenyang Key Laboratory of High Performance Plastics Engineering, Shenyang University of Chemical Technology, Shenyang 110142, China.*

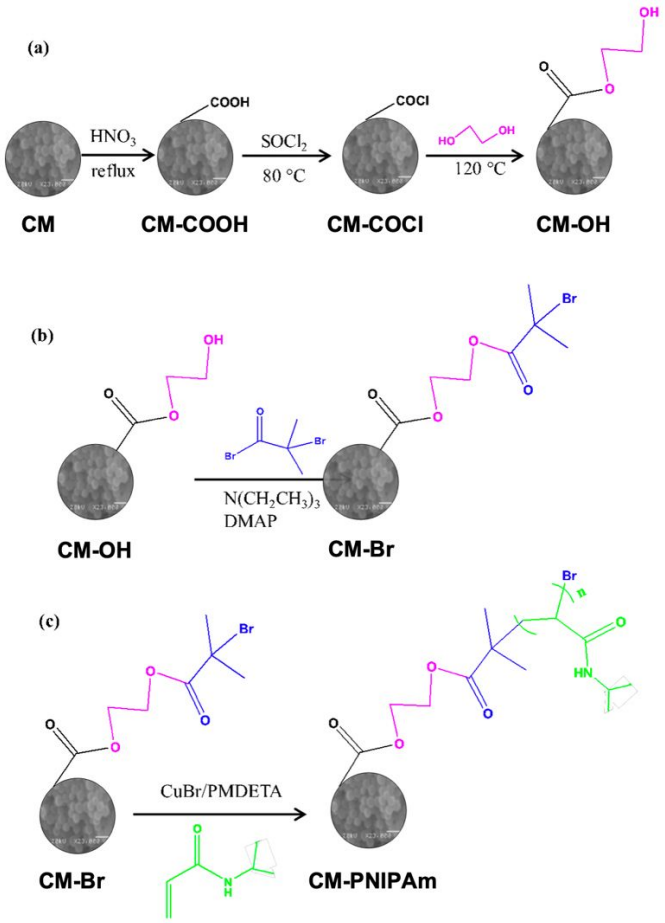

Figure S1. Schematic illustration of the grafting process. (a, b) Macroinitiator preparation, (c) polymerization of PNIPAm from the surface of the carbon microsphere (CM).

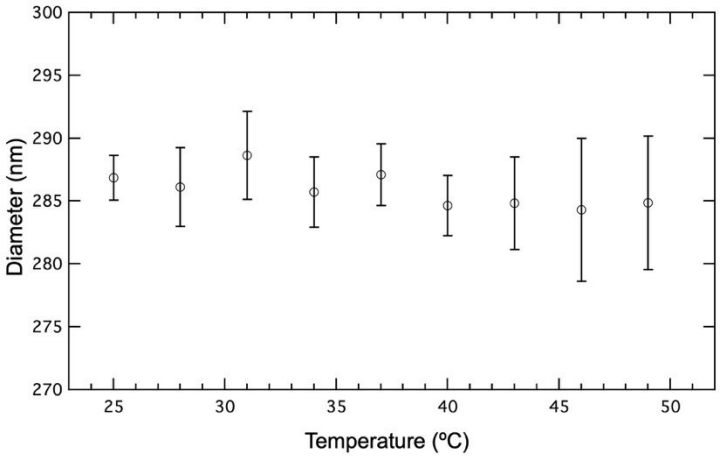

Figure S2. DLS measurements of average particle size of PNIPAm-grafted CM dispersed in deionized water within a temperature range from 25 to 50 °C. The concentration of particles is 0.1 mg/ml. Each data point is an average of 6 individual measurements along with their corresponding standard deviations.

Because of the relatively large error in the DLS measurements, we do not see a change in particle size as temperature is increased beyond the LCST. Furthermore, we do not see the presence of aggregates at high temperatures presumably because of the relatively low concentration of PNIPAM-grafted carbon microspheres used to collect the DLS data. Higher concentrations of PNIPAM-grafted carbon microspheres beyond 0.1 mg/ml led to significant light scattering.

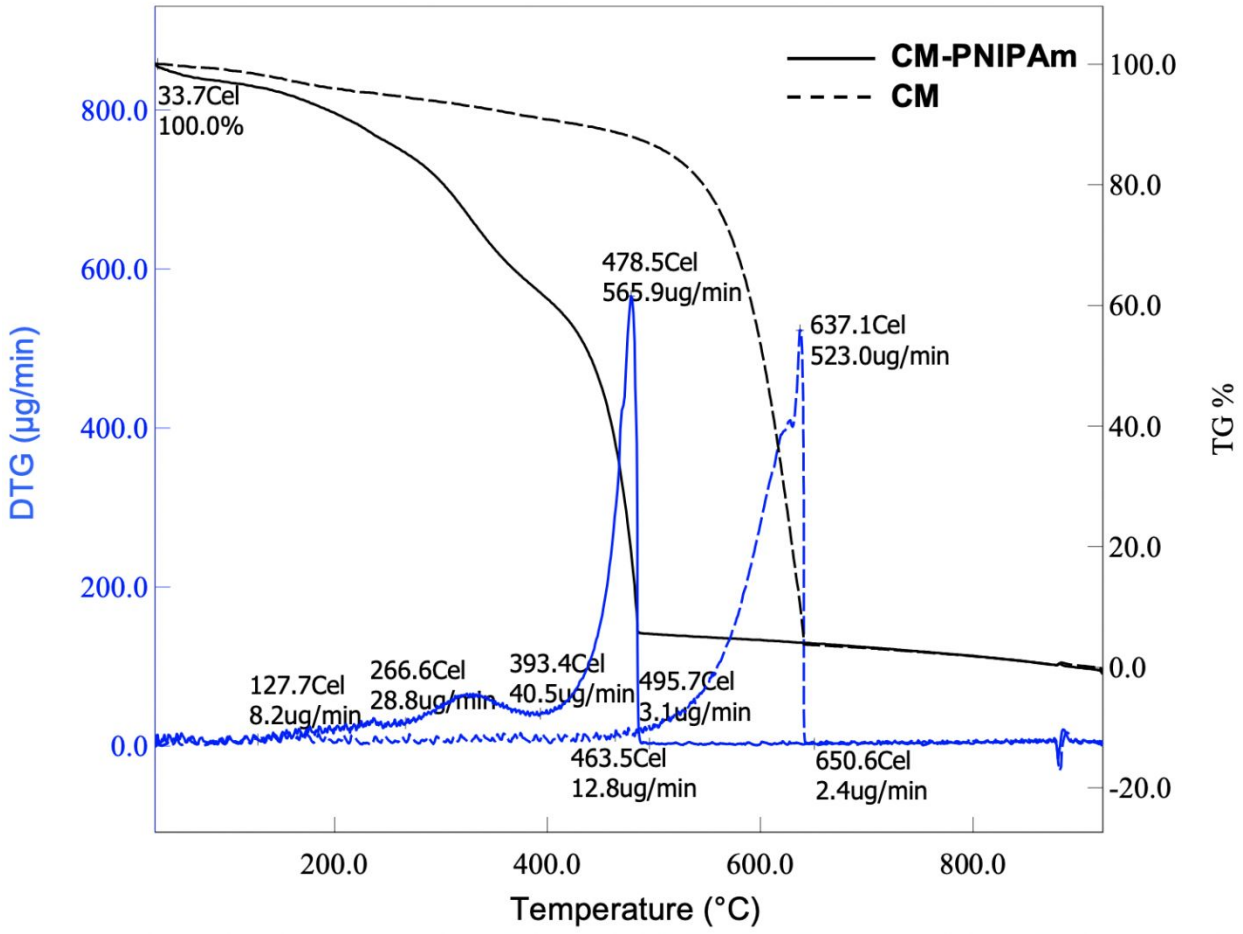

Figure S3. Thermogravimetry (TG) and derivative thermogravimetry (DTG) data.

Thermal gravimetric analysis (TGA) of CM and PNIPAm-grafted CM were carried out by using a thermo gravimetric analyzer (Seiko, SII EXSTAR6000) under dry air at a flow rate of 150 ml/min and a heating rate of 15 °C/min. Approximately 4 mg of the sample was placed in ceramic crucibles and the weight loss was recorded over the temperature range 50-900 °C.

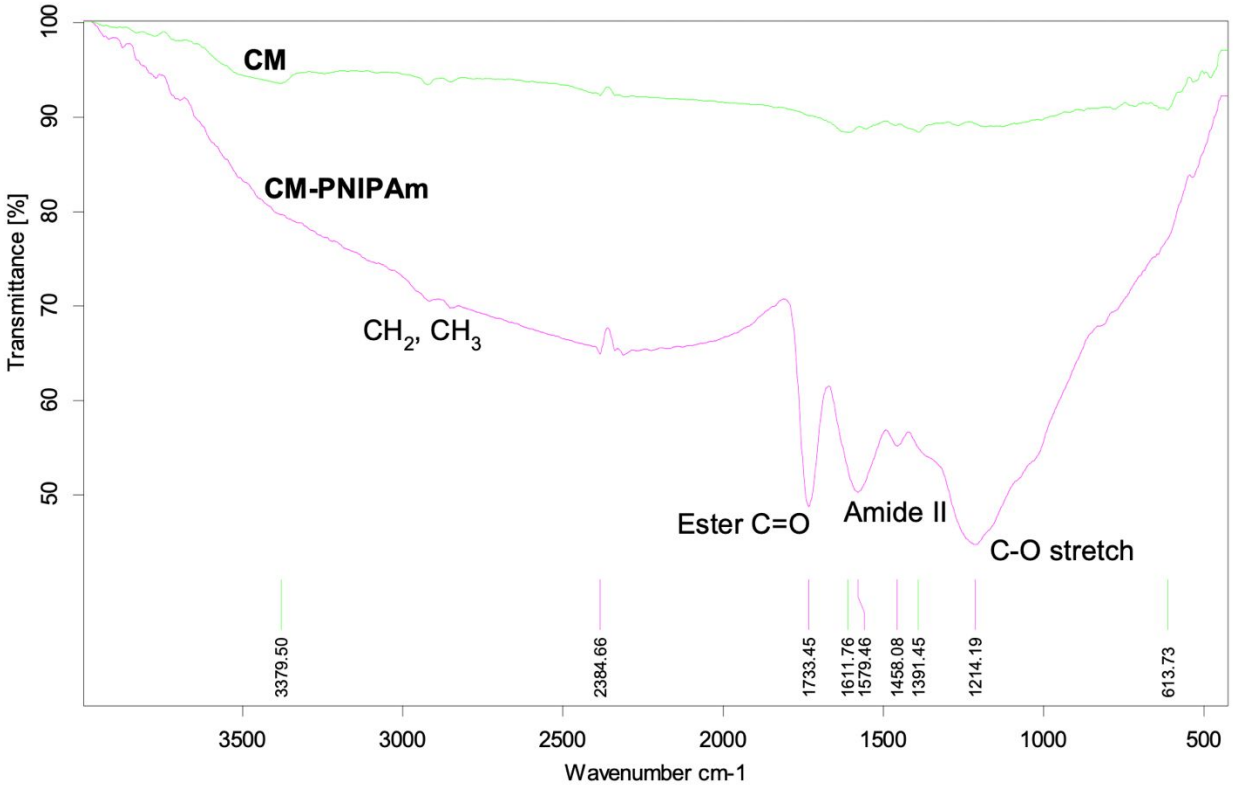

Figure S4. FTIR spectra of CM and PNIPAm-grafted CM.

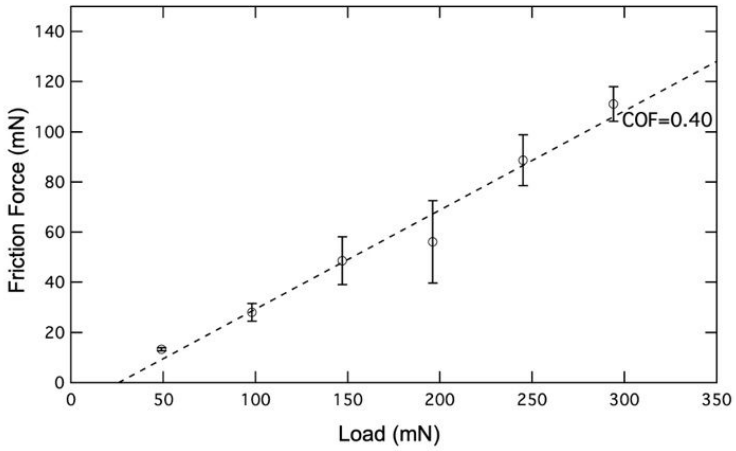

Figure S5. Plot of friction force versus applied load between a shearing borosilicate spherical lens and a flat silicon wafer using DI water only at room temperature. Data points were fitted to a straight line with the slope corresponding to the coefficient of friction (CoF). The shear velocity is 0.5 mm/s over a distance of 10 mm. Error bars represent the standard deviation of friction force obtaining from at least 5 trials.

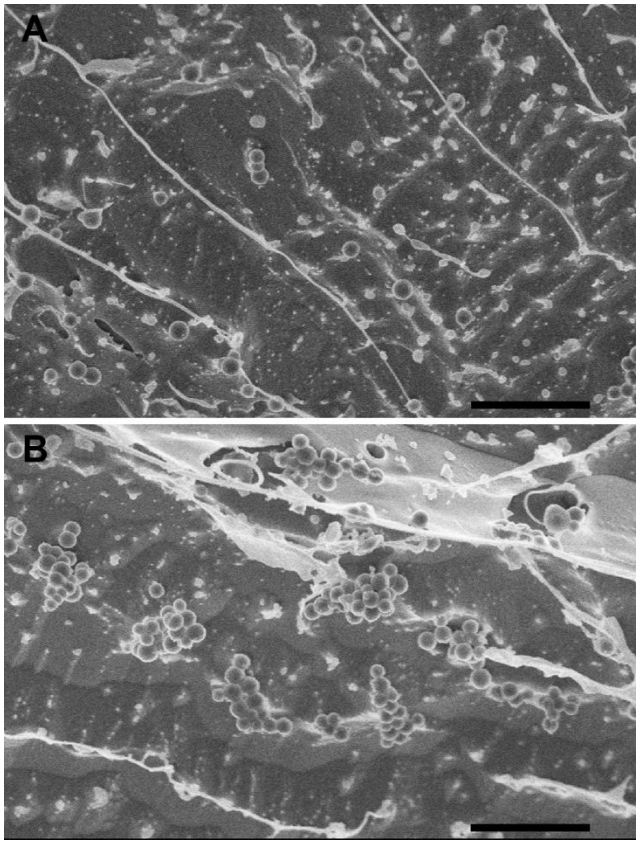

Figure S6. Cryo-SEM images PNIMAm-coated CM. (A) Low temperature, and (B) high temperature samples with a concentration of 1 mg/ml PNIMAm-coated CM particles.

Figure S5 shows cryo-SEM images of PNIMAm-coated CM at low and high temperatures. A 1 mg/ml PNIMAm-coated CM sample was prepared. Half of the sample volume was left at room temperature while the other half was heated to 50 °C. Since the aggregation process is irreversible once the temperature of the sample is increased (unless the sample is sonicated to re-disperse the particles), cryo-SEM captured the state (i.e., aggregates or singlets) of the particles. We were unable to quantify the degree of aggregation. Although aggregates were present at both low and high temperatures, the number and size of aggregates were larger in the high temperature sample.

TABLE S1. Values of the slopes and y-intercepts for the modified Amontons' Equation [Eq. 1] used to determine the linear fits of the for Figures 3 and 4.

	Low temperature		**High temperature**	
Concentration (mg/ml)	Slope, μ	y-intercept, F_o (mN)	Slope, μ	y-intercept, F_o (mN)
1	.37 ± .001	-3.52 ± 1.88	.47 ± .019	-5.68 ± 3.52
3	.21 ± .014	-3.07 ± 2.65	.36 ± .030	-3.69 ± 5.63
5	.04 ± .002	3.59 ± 0.41	.11 ±. 004	4.27 ± 0.70
10	.04 ± .001	2.44 ± 0.15	.07 ±. 003	2.86 ± 0.49