# Surface-immobilised micelles via cucurbit[8]uril-rotaxanes for solvent-induced burst release

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# Materials

All starting materials were purchased from Sigma Aldrich and used as received unless stated otherwise. Methyl methacrylate (MMA) and N-hydroxyethyl acrylamide (HEAA) monomers were passed through a column of silica gel and purged with high purity nitrogen for 1 h prior to use. 2-(2-(2-(naphthalen-2-yloxy)ethoxy)ethoxy)ethyl acrylate (NpA) monomer was synthesised as previously reported.[1] Cucurbit[8]uril (CB[8]) based rotaxanes on Au surface were prepared as documented previously.[2] All aqueous solutions were prepared in deionized water treated with a Milli-QTM reagent system with a resistivity of 18.2 MΩ/cm at 25 °C.

# Instrumentation

$^1$H NMR and $^{13}$C NMR spectra were recorded on a Bruker Avance QNP 400 MHz. ESI-MS was performed on a Fischer Thermo Scientific LTQ Velos Ion Trap Mass Spectrometer. UV-vis spectra were recorded on a Varian Cary 4000 UV-vis spectrophotometer. Fluorescence microscopy was performed on a Leica DMI 4000B microscope. AFM image and force-distance curves were recorded on a Agilent (now Keysight Technologies) 5500 AFM machine with a FESPA tip from Bruker. AFM force-distance curves displayed in this work are averaged over multiple areas from representative surfaces.

# Experimental

## Synthesis of amphiphilic diblock copolymer 2

Amphiphilic diblock copolymer poly(MMA)-block-poly(HEAA) containing Np pendant groups was synthesised *via* a two-step reversible addition-fragmentation chain transfer (RAFT) polymerisation using chain transfer agent 4-cyano-4-[(dodecylsulfanylthiocarbonyl)sulfanyl]-pentanoic acid (CDTPA). Step 1: To a two-necked round bottom flask was added CPTPA (34.6 mg, 0.1 mmol, 1 eq.) and MMA (1.6 g, 16 mmol, 160 eq.) in a butanone solution

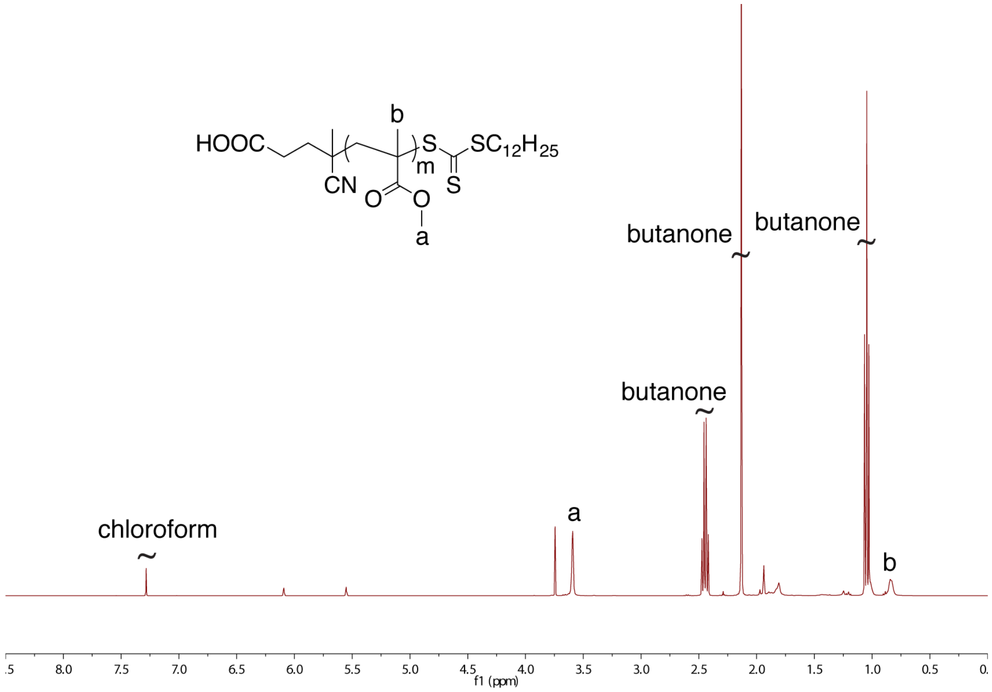

Figure S1: $^1$H NMR spectrum of polymer **1**.

(5 ml). Oxygen was removed by bubbling argon through the solution for 20 min, followed by the addition of 4,4-azobis(4-cyanovaleric acid) (ACPA, 8.4 mg, 0.03 mmol, 0.3 eq.). The flask was then immersed in a pre-heated oil bath (65 °C) and the solution stirred at 400 rpm for 36 h. The resultant polymer was precipitated in cold hexane and dried under vacuum. The formed polymer **1** was characterised to give $M_w = 13.5$ kDa, $M_n = 11.3$ kDa, PDI = 1.2 from THF-GPC, MMA conversion = 75% from $^1$H NMR (Figure S1).

Step 2: To a two-necked round bottom flask was added polymer **1** (270 mg, 0.02 mmol, 1 eq.), HEAA (207 mg, 1.8 mmol, 90 eq.) and NpA (69 mg, 0.2 mmol, 10 eq.) in a butanone solution (4 ml). Oxygen was removed by bubbling argon through the solution for 20 min, followed by addition of ACPA (3 mg, 0.01 mmol, 0.5 eq.). The flask was then immersed in a pre-heated oil bath (65 °C) and the solution stirred at 400 rpm for 24 h. The resultant polymer was precipitated in cold hexane and dried under vacuum. The formed polymer **2** was characterised to give $M_w = 27.0$ kDa, $M_n = 19.3$ kDa, PDI = 1.4 from THF-GPC, [MMA] : [Np] = 1 : 0.06 from $^1$H NMR (Figure S2).

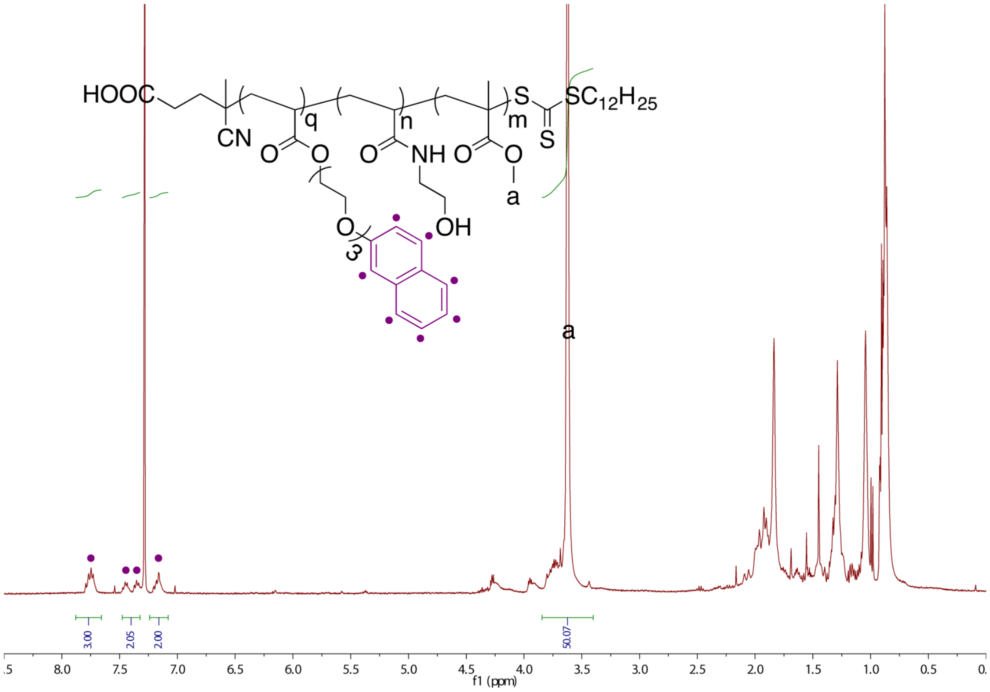

Figure S2: $^{1}$H NMR spectrum of polymer **2**

## General method for micellisation and surface immobilisation

A typical procedure for the preparation of micelle solution is as follows: 6.95 mg of amphiphilic diblock copolymer **2** was dissolved in 3 mL of THF. Under vigorous stirring (400 rpm), 5 mL of deionised water was added slowly. After the addition process was completed, the micelle solution was further stirred for another 24 h until THF evaporated.

In order to immobilise NFMs on the Au surface, the CB[8]-rotaxane functionalised substrate was immersed into a solution of NFMs ([Np] = 0.5 mM) for 30 s, washed with copious amounts of water, and dried under a stream of nitrogen. The formation of a well-defined monolayer of micelles was confirmed by AFM (Figure S3A), in contrast to the physisorbed multilayer formed by casting micelles onto a bare glass slide. The partial collapse and complete breakdown of the monolayer of NFMs were recorded by AFM, as shown in Figure S3B and Figure S3C, respectively.

For patterned surfaces, polydimethylsiloxane (PDMS) stamps were wetted by EtOH solutions of 2-aminoethanethiol hydrochloride (20 mM) and then brought into contact with

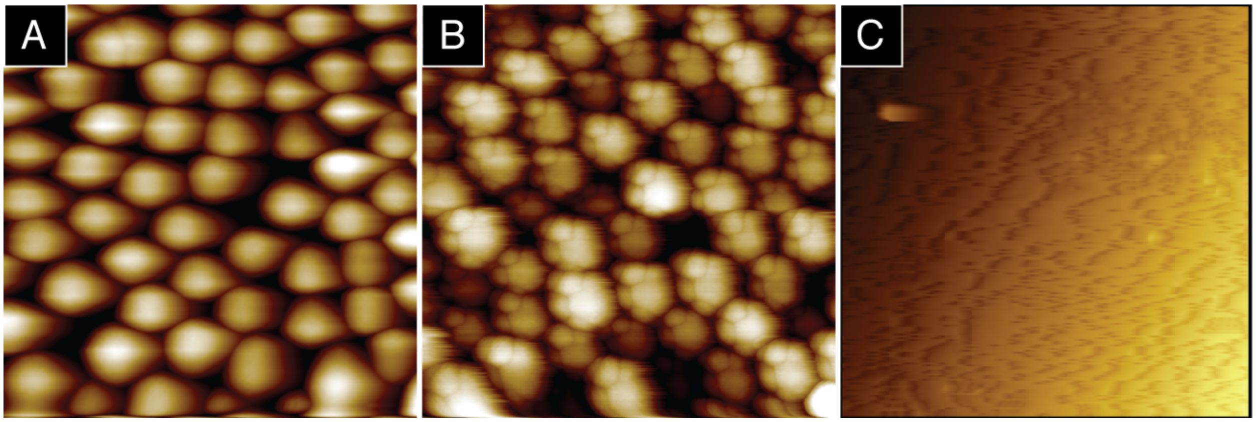

Figure S 3: AFM images (1 μm × 1 μm) of surface-bound NFMs (A) after preparation; (B) after 1 s immersion in THF; (C) after 1 min immersion in THF. All images were recorded in air in tapping mode.

bare Au substrates for 30 s. After peeling away the stamps, the resulting substrates were washed with EtOH and immersed into solutions of dodecanethiol (2 mM) to backfill the bare areas. Surface-bound CB[8]-rotaxanes were subsequently prepared on the patterned areas where amino groups were present, with the same method used for the unpatterned surfaces. The resultant substrates with patterned CB[8]-rotaxanes were then immersed into aqueous solutions of micelles and left on a shaker at 200 rpm for 30 min.

## Morphology change of NFMs and NR-loaded NFMs upon exposure to THF

Au substrates with immobilised NFMs or NR-loaded NFMs were dipped into THF for 1 min, then quickly removed and dried with a stream of nitrogen. Force spectra were then recorded (Figure S4, S5).

## Release profile of the NR-loaded surface immobilised micelles

In order to study the release rate of the NR-loaded micelles, a substrate (1 cm$^2$) with surface-immobilised NR-loaded NFMs was dipped into THF (1 L), and the UV/vis absorbance spectra of the THF solution were recorded at different time intervals. As shown in Figure S6,

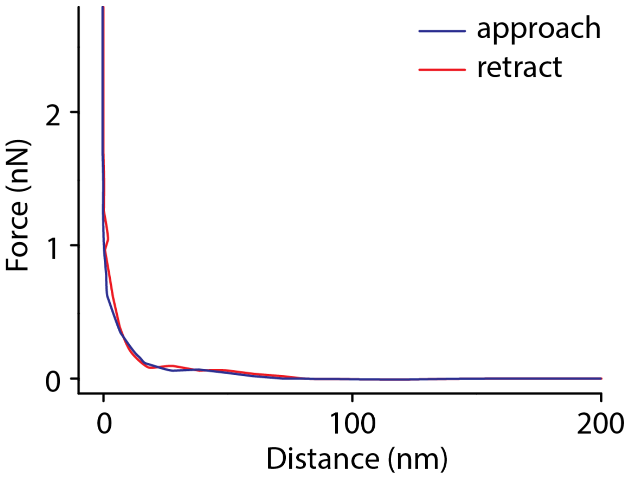

Figure S4: Approach and retract force curves between a bare Si tip and collapsed NFMs on a CB[8]-rotaxane functionalised Au surface. Spectra were recorded in air.

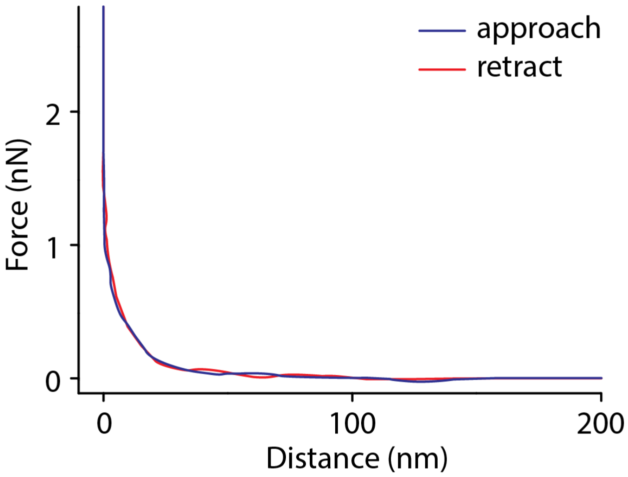

Figure S5: Approach and retract force curves between a bare Si tip and collapsed NR-loaded NFMs on a CB[8]-rotaxane functionalised Au surface. Spectra were recorded in air.

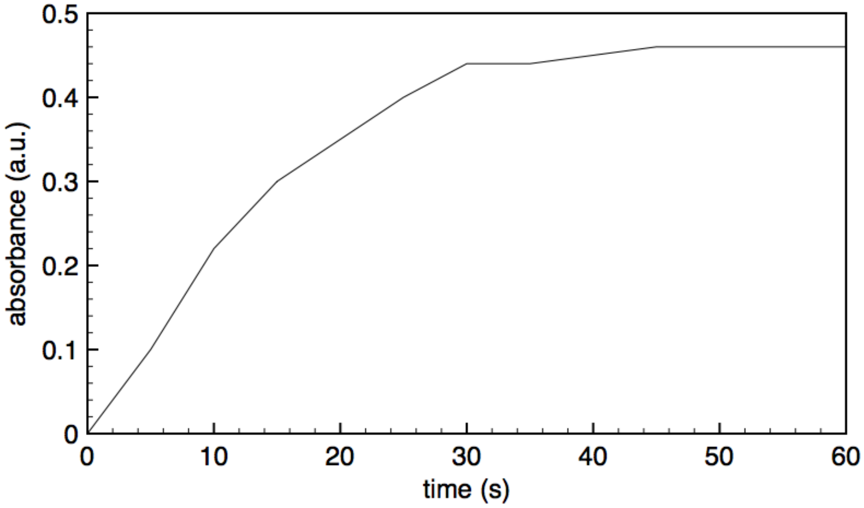

Figure S6: Plot of UV/vis absorbance at $\lambda_{max} = 525$ nm *vs.* dipping time in THF, showing the release profile of the NR-loaded NFMs.

the absorbance of the resultant THF solution at $\lambda_{max} = 525$ nm increased rapidly during the first 30 s, then reached a plateau with a relatively constant absorbance until 60 s.

## References

(1) Geng, J.; Biedermann, F.; Zayed, J. M.; Tian, F.; Scherman, O. A. *Macromolecules* **2011**, *44*, 4276–4281.

(2) Hu, C.; Lan, Y.; Tian, F.; West, K. R.; Scherman, O. A. *Langmuir* **2014**, *30*, 10926–10932.