Electronic Supplementary Information

Synthesis of microspheres-loaded porous polymers by combination of emulsion and dispersion polymerisations in supercritical carbon dioxide

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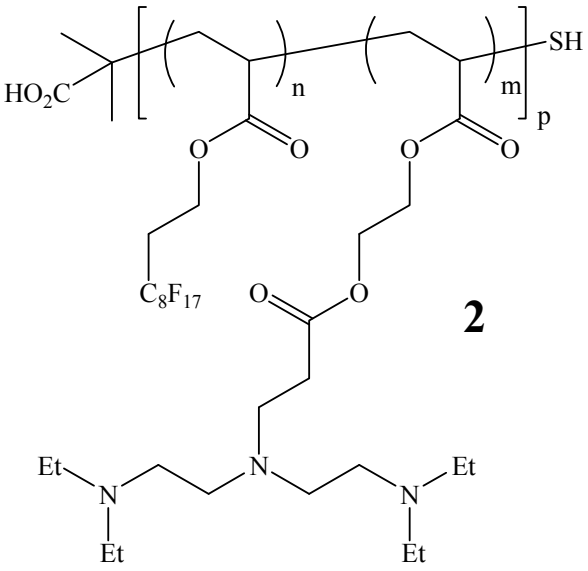
Materials and methods. D(+)-Mannose (for microbiology, ≥99%, Fluka) and α,α'-Azobisisobutyronitrile (AIBN, ≥98.0%, Fluka), immobilised lipase B from *C. antarctica* (CALB, E.C.3.1.1.3, ≥2 U/mg, Aldrich), 2-methyl-2-butanol (*ReagentPlus*®, 99% Aldrich), 3-mercaptopropionic acid (≥99% Aldrich), dimethylphenylphosphine (DMPP, 99 %, Aldrich), acrylamide (AM, 97%, Aldrich), *N*,*N*′-Methylenebisacrylamide (MBAM, 96%, Acros), potassium persulfate ($K_2S_2O_8$, Merck Chemicals), poly(vinyl alcohol) (PVOH, Alcotex 72.5% hydrolyzed) and carbon dioxide (CO_2, Air liquide, N48) were used as received. Dimethylformamide (DMF, >99%, Acros) and the Zonyl® TM fluoromonomer (from 4 to 20 fluorinated carbons, M_w = 534 g/mol, Aldrich) were dried over CaH_2 and distilled under reduced pressure. The highest molecular weight methacrylacrylate derivatives of Zonyl were eliminated during the distillation (Fig. S2 A). The average molar mass of distilled Zonyl® was evaluated at 412 g/mol by ^{1}H NMR in $CDCl_3$ using 1,4-dioxane as an internal reference standard (comparison of olefinic protons signals of the methacrylate monomer at δ_H 1.94; 2.51 ; 4.45 ; 5.61 ; 6.13 ppm with the dioxane signal at δ_H 3.69 ppm). The density of the distilled Zonyl was equal to 1.55 g mL^{-1}. The perfluorinated polyacrylate copolymer **2** (M_n = 12000 g mol^{-1}, m = 3 tetraethyldiethylenetriamine (TEDETA) units per chain, n = 20 units of heptadecafluorodecyl acrylate per chain) was synthesized following a procedure reported by Grignard *et al.* (*Chem. Commun.*, 2008, **3**, 314-316). CO_2 was pressurised into stainless steel reactors (12 cm^3) using an Isco 260D syringe pump. The initial pressure in the reactor was measured with an Isco D-Series Pump Controller and on the reactor with WIKA pressure gauge 0-600 bar. A PTFE poly(tetrafluoroethylene) bar was used to stir into the reactor before polymerisation.



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Characterisation. Infrared spectra were recorded on a Perkin–Elmer Spectrum One FTIR spectrometer with samples prepared as KBr pellets. ^{1}H and ^{13}C NMR spectral studies, and 1H-1H (COSY), 1H-^{13}C (HSQC) correlation experiments were carried out at 25°C with a Varian spectrometer at 600 and 150 MHz, respectively. Chemical shifts are given in d-units measured downfield from $MeSi_4$ at 0 ppm. High-resolution mass spectra were acquired on a ESI-FT-ICR SolariX spectrometer (Bruker) in positive-ion mode. External calibration was done over the scan range of m/z 150-900 using H_3PO_4 adducts and the mean residual error obtained was <0.5 ppm. Distilled Zonyl® was analysed at 3.3 μM in 1:1 acetonitrile-water solution supplemented with 0.33 μM GluFib (internal calibrant). The mixture of glycosurfactants **1** was prepared with the same method added to 33 μM LiI (cationising compound). The pore size distribution and the total pore volume were determined by mercury porosimetry (ThermoQuest Pascal 140 and 240). The Washburn equation (E.W. Washburn, *Phys. Rev.*, 1921, **17**, 273) was used to calculate the pore diameter, *d,* in relation to the external pressure, P, applied to force mercury, a non-wetting liquid, into the pores and by assuming that intrusion is the only phenomenon occurring. The pore volume was measured in a large pressure range, from 0.05 up to 200 MPa, which corresponds to pore diameters ranging from 30 μm to 7.5 nm. The porous polymer materials were analysed by scanning electron microscopy (SEM) with a Jeol JSM 840-A after metallisation with Pt (30 nm). Stress-strain curves were recorded at room temperature with an Instron tester (model DY24) equipped with 500 N static cell at a 0.1 mm/min compression speed. The compression modulus was calculated from the slope in the linear regime between 3 and 7% deformation. At least four measures were performed for each sample.

Synthesis of the fluorinated sugar surfactant 1 (Fig. S1). 6-O-(3-mercaptopropanoyl)-D-mannopyranose (1.5 g, 5.6 mmol, 1.2 equiv), prepared by enzymatic reaction following a previously reported procedure (C. Boyère *et al.*, *Carbohydr. Res.*, 2011, **346**, 2121-2125) (see Figure S1, step 1), and distilled Zonyl® methacrylate (1.9 g, M_w = 416 g mol^{-1}, d = 1.55 g mL^{-1}, 4.6 mmol) were placed in a 50 mL flask under inert atmosphere. A solution of dimethylphenylphosphine (DMPP) (38 mg, 0.28 mmol, 0.05 equiv) in dry and degassed DMF (30 mL) was added to the reaction medium and stirred for 16 h at room temperature (see Figure S1, step 2). The product was purified by column chromatography on silica gel using 9:1 CH_2Cl_2–MeOH as eluent. Stepwise control of the reactions has been readily achieved by analytical TLC performed using Silica Gel 60 F_{254} plates (E. Merck, Germany) with 9:1 CH_2Cl_2–MeOH followed by charring with vanillin-H_2SO_4. The expected fluorinated sugar **1** was collected in 84% yield (85:15 α/β mixture). A mass spectrometry analysis revealed that **1** mainly consists in a mixture of fluorinated sugar derivatives whose side chains contain 6, 8 or 10 fluorinated carbons (See Fig. S2).

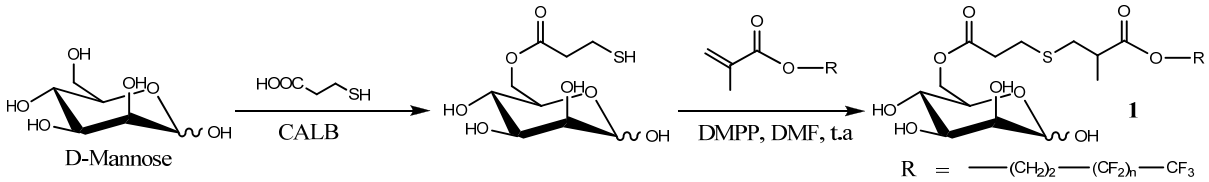
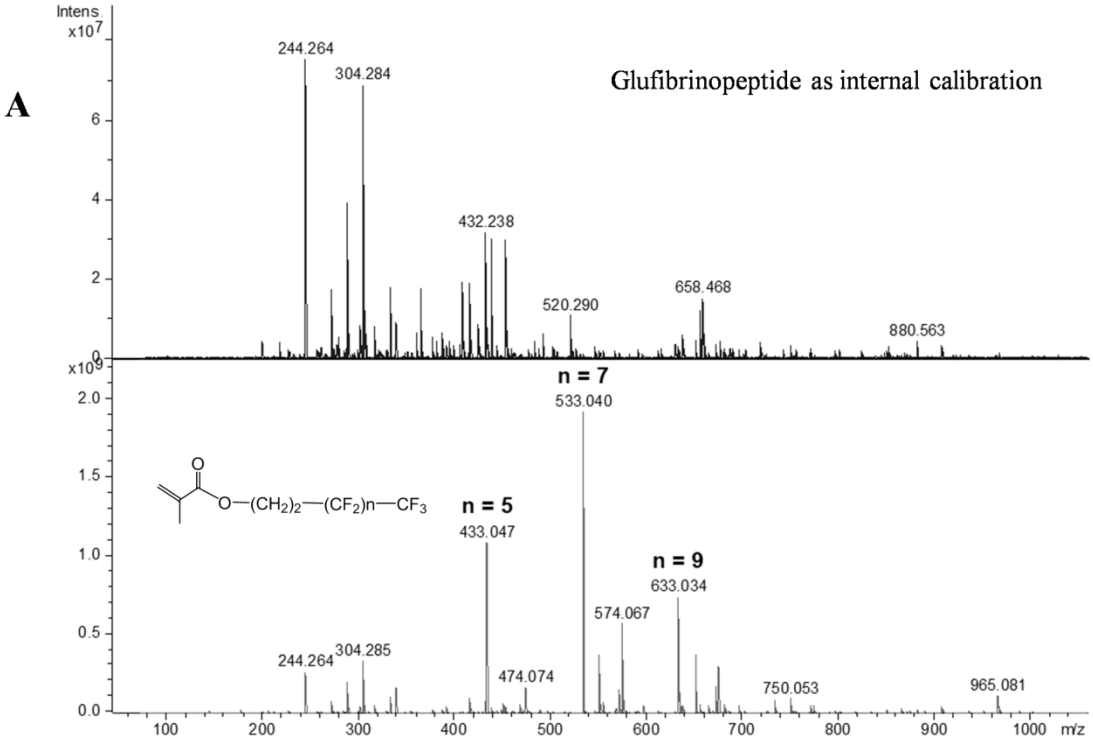
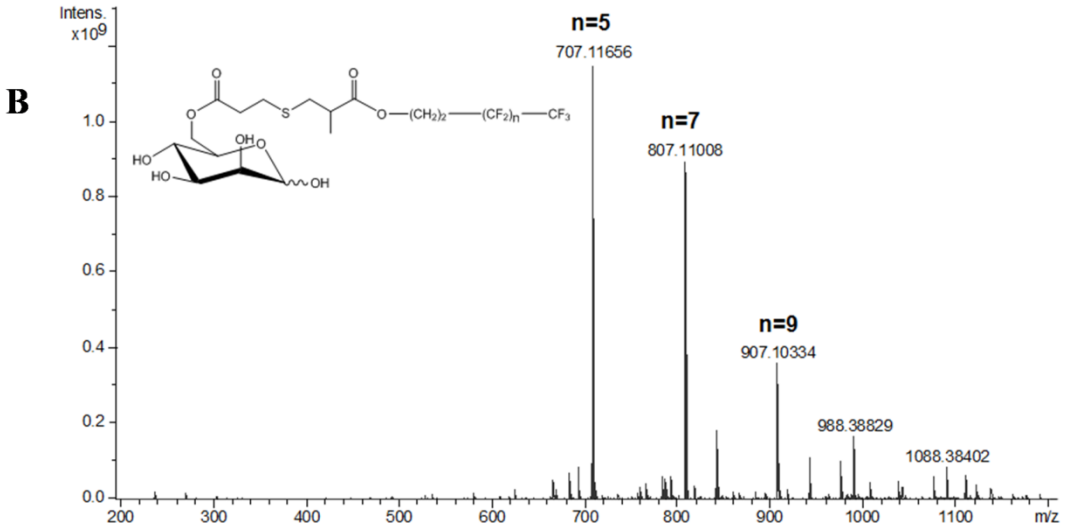


Fig S1. General strategy combining enzymatic esterification and base-catalysed Michael addition reaction for the synthesis of the fluorinated carbohydrate ester **1**.

R_f 0.28 (9:1 CH_2Cl_2–CH_3OH) ; IR (KBr): ν_{max} = 1737 cm^{-1} (C=O). ^{1}H NMR (600 MHz, CD_3OD, TMS): δ 1.23 (d, *J* 7.2 Hz, 3H, H-7'); 2.64 (m, 2H, H-11'); 2.64 (m, 2H, H-2'); 2.67 (m, 2H, H-3'); 2.74 (m, 1H, H-6'); 2.86 (m, 2H, H-5'); 3.64 (t, *J* 9.0 Hz, 1H, H-4); 3.76 (dd, *J* 3.6 and 9.6 Hz, 1H, H-3); 3.79 (m, 1H, H-2); 3.92 (m, 1H, H-5); 4.28 (dd, *J* = 6 Hz,1H, H-6a); 4.43 (m, 1H, H-6b); 4.43 (m, 2H, H-10'); 4.74 (br s, 1H, H-1β); 5.04 (br s, 1H, H-1α); NMR ^{13}C (150 MHz, CD_3OD, TMS): δ 15.55 (1C, C-7'); 26.72 (1C, C-3'); 29.75 (1C, C-11'); 34.38 (1C, C-5'); 34.61 (1C, C-2'); 40.02 (1C, C-6'); 56.71 (1C, C-10'), 64.24 (1C, C-6); 67.31 (1C, C-4); 70.17 (1C, C-5); 70.74 (1C, C-3); 71.36 (1C, C-2); 94.50 (1C, C-1β); 94.53 (1C, C-1α); 172.26 (1C, C=O (1')); 174.80 (1C, C=O (8')); ESI-FT-ICR MS+ calculated for $C_{21}H_{25}F_{13}O_9S$ (**1**, n = 5) $[M+Li]^+$ *m/z* : 707.1167 ; found 707.1166; calculated for $C_{23}H_{25}F_{17}O_9S$ (**1**, n = 7) $[M+Li]^+$ *m/z* : 807.1103; found 807.1101; calculated for $C_{25}H_{25}F_{21}O_9S$ (**1**, n = 9) $[M+Li]^+$ *m/z* : 907.1039, found 907.1033.



ESI-FT-ICR MS+ calculated for $C_{12}H_9F_{13}O_2$ (n = 5) $[M+H]^+$ *m/z* : 433.0468 ; found 433.0469; calculated for $C_{14}H_9F_{17}O_2$ (n = 7) $[M+H]^+$ *m/z* : 533.0404; found 533.0401; calculated for $C_{16}H_9F_{21}O_2$ (n = 9) $[M+H]^+$ *m/z* : 633.0340, found 633.0338.



ESI-FT-ICR MS+ n= 5 $[C_{21}H_{25}O_9SF_{13}+Li]^+$ at m/z = 707.12, n = 7$[C_{23}H_{25}O_9SF_{17}+Li]^+$ at m/z = 807.11, n = 9 $[C_{25}H_{25}O_9SF_{21}+Li]^+$ at m/z = 907.10.

Fig. S2. ESI-MS analysis of (**A**) the distilled Zonyl® and (**B**) the fluorinated compound **1** using glufibrinopeptide as internal calibration.

Synthesis of polyHIPEs in $scCO_2$ with 1 as surface active agent. PVOH (5% w/v based on water, 72.5% hydrolysed) and the surfactant **1** (48 mg, 5 wt% based on monomers, 0.06 mmol) were dissolved in milli-Q water (1.45 mL) using ultrasound. This aqueous solution was placed in a stainless steel reactor (12 cm^3) and added with a mixture of AM (768 mg, 10.80 mmol) and MBAM (192 mg, 1.20 mmol) (40% w/v of monomers in final aqueous phase) and the $K_2S_2O_8$ initiator (19 mg, 2 wt% based on monomers). Under stirring at 300 rpm with a magnetic bar, the vessel was purged for few minutes with CO_2 before pressurisation with liquid CO_2 (20±2°C, 100±5 bar). After 30 min, the temperature was increased gradually until 60°C (P_{final} = 250±20 bar). After 16 h, the reactor was cooled at room temperature and slowly vented. A hydrated polymer matrix was obtained. The hydrated porous polymer was frozen with liquid nitrogen and lyophilised for 24 h in order to remove water while preserving the porous structure. The final polyHIPE was analysed by SEM, porosimetry, mercury pycnometry, compressive stress-strain analysis (see Table 1 samples A) and N_2 adsorption-desorption

Synthesis of PMMA-loaded polyHIPEs in $scCO_2$. MMA (500 mg, 2.5:1 w/w based on the polyHIPE sample A), AIBN (10 mg, 2 wt% based on MMA) and the fluorinated copolymer **2** (25 mg, 5 wt% based on MMA, Mn = 12000 g mol^{-1}) were placed at the bottom of a stainless steel reactor (12 cm^3). A piece of the lyophilised polyHIPE (sample A, 200 mg) was deposed on an inert support (metallic copper) in the upper part of the reactor. After a few minutes purge with CO_2, the reactor was stirred at 300 rpm with a magnetic bar, pressurised with liquid CO_2 (20±2°C, 100±5 bar) and heated at 65°C (P_{final} = 320±20 bar). After 16 h, the reactor was cooled and vented. The modified polyHIPE (Sample B) was analysed by SEM, porosimetry, pycnometry, BET and compressive stress-strain analysis (see Table 1 sample B). The same experiment was repeated with amount of MMA 5:1 w/w compared to the polyHIPE (see Table 1, sample C) but also in the absence of the stabiliser **2** (see Table 1, samples D and E).

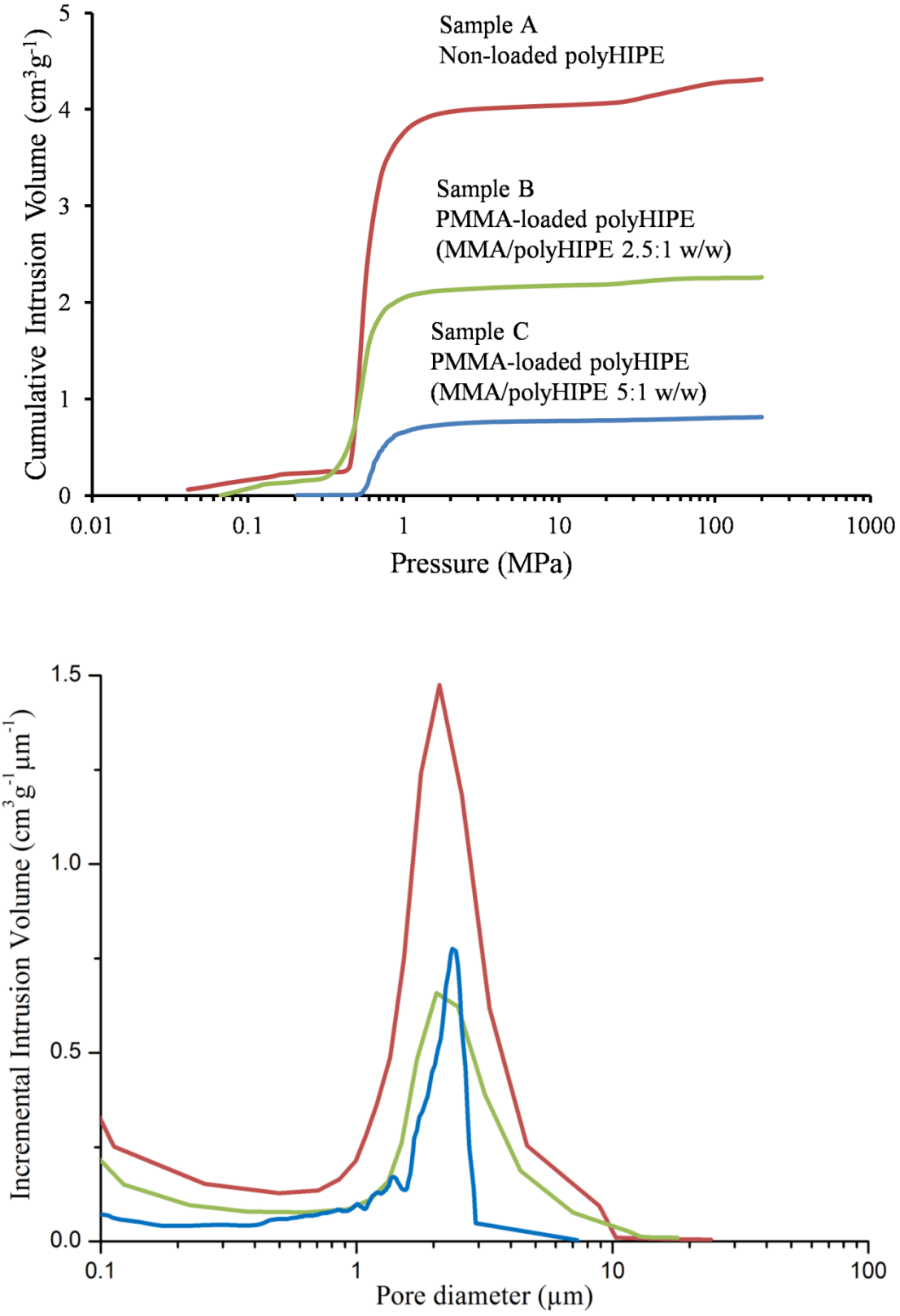


Fig. S3. Mercury intrusion porosimetry data for the acrylamide polyHIPE sample A (red) and the derived materials modified by MMA polymerisation in the presence of the surfactant **2** (samples B (green) and C (blue)). See Table 1 entries A-C for the preparation of the samples.

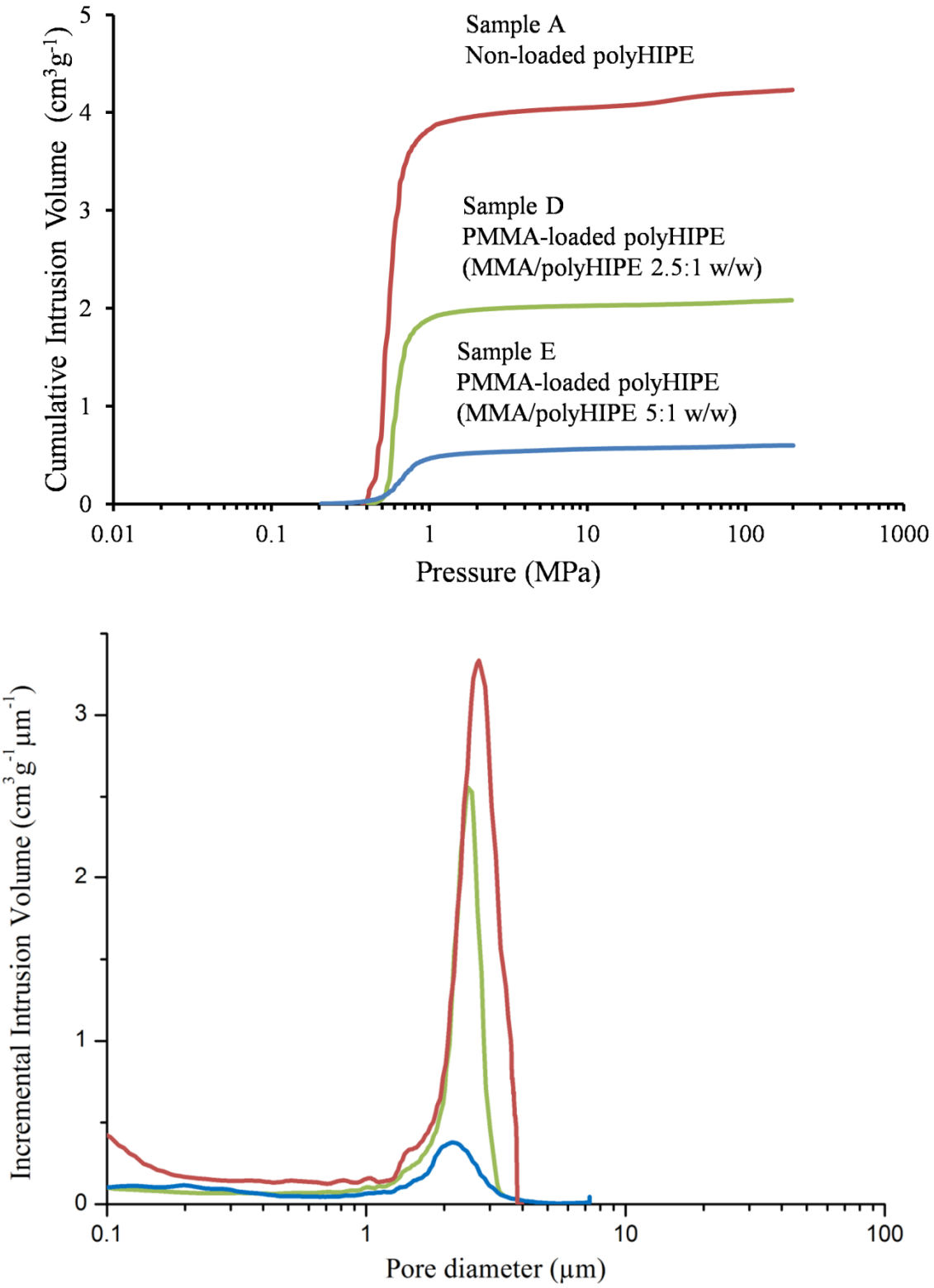


Fig S4. Mercury intrusion porosimetry data for the acrylamide polyHIPE sample A (red) and the derived materials modified by MMA polymerisation in the absence of the surfactant **2** (samples D (green) and E (blue)). See Table 1 entries A, D and E for the preparation of the samples.

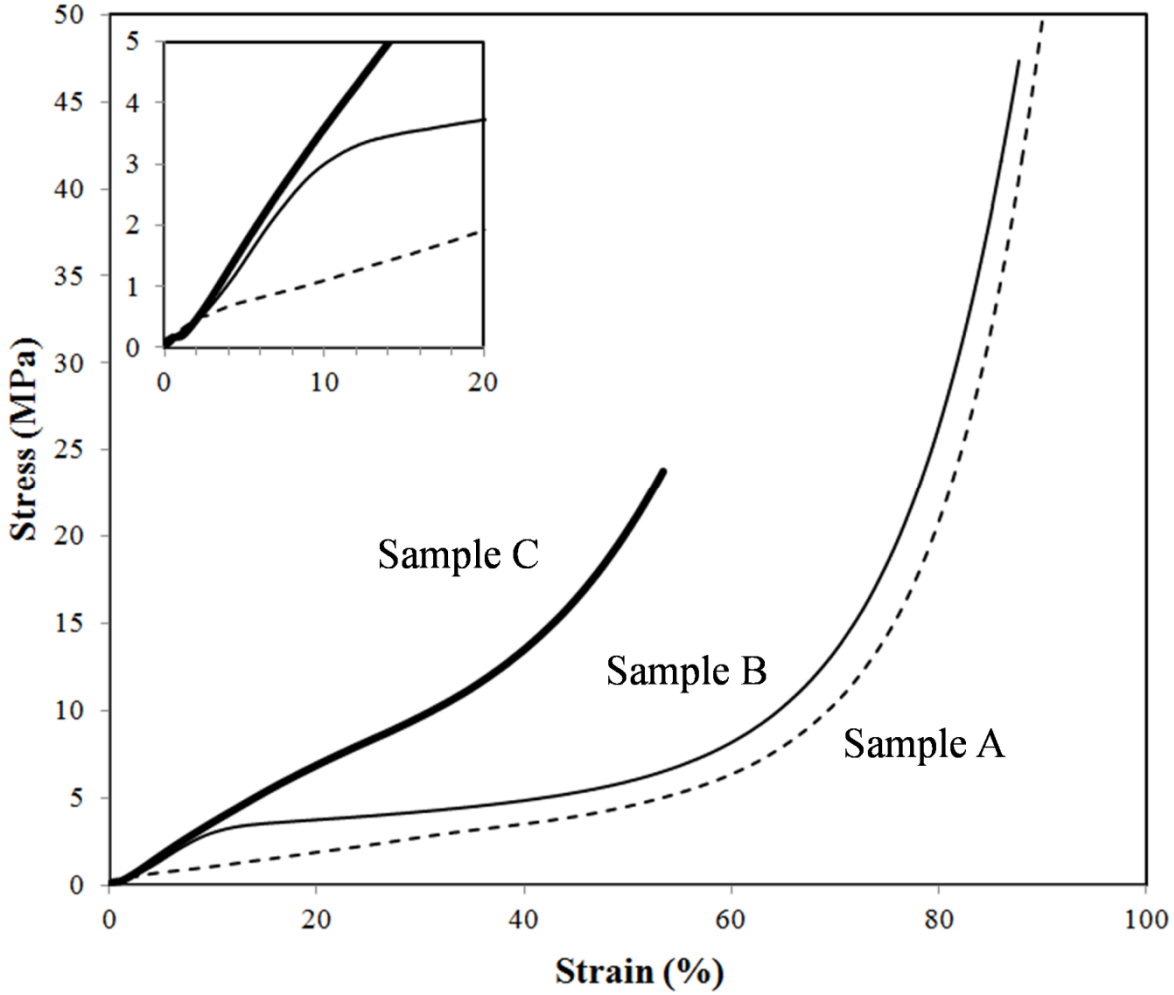


Fig. S5. Compressive stress-strain curves for the acrylamide polyHIPE sample A (dotted line) and the derived materials modified by MMA polymerisation in the presence of the surfactant **2** (sample B (full line), MMA/polyHIPE 2.5:1 w/w and sample C (bold line), MMA/polyHIPE 5:1 w/w). See Table 1 entries A-C for the preparation of the samples.

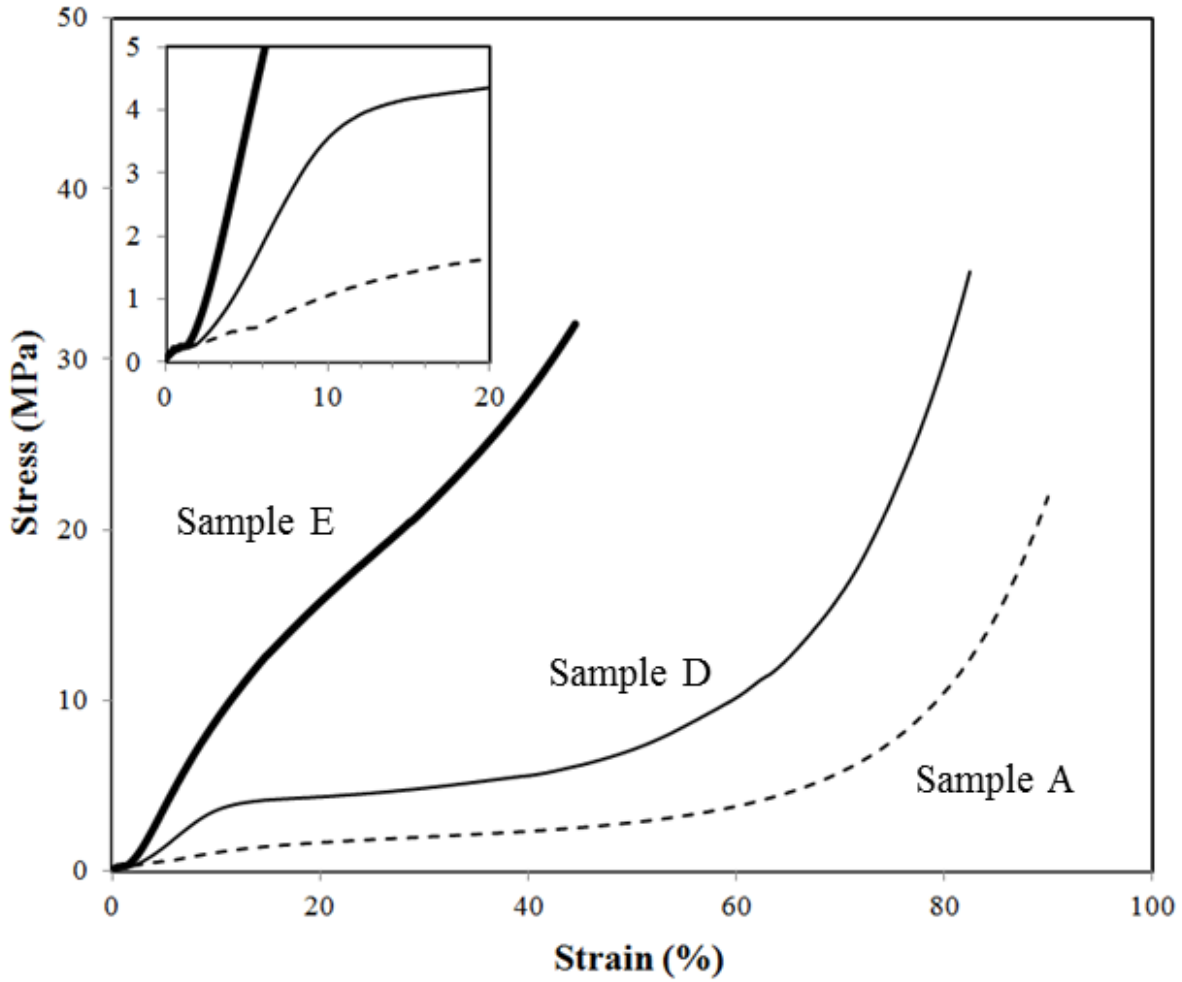


Fig. S6. Compressive stress-strain curves for the acrylamide polyHIPE sample A (dotted line) and the derived materials modified by MMA polymerisation in absence of the surfactant **2** (sample D (full line), MMA/polyHIPE 2.5:1 w/w and sample E (bold line), MMA/polyHIPE 5:1 w/w). See Table 1 entries A, D and E for the preparation of the samples.