Electronic Supplementary Material (ESI) for Lab on a Chip
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Lab on a Chip
Supplementary Information

Smart hydrogels as storage elements with dispensing functionality in discontinuous microfluidic systems

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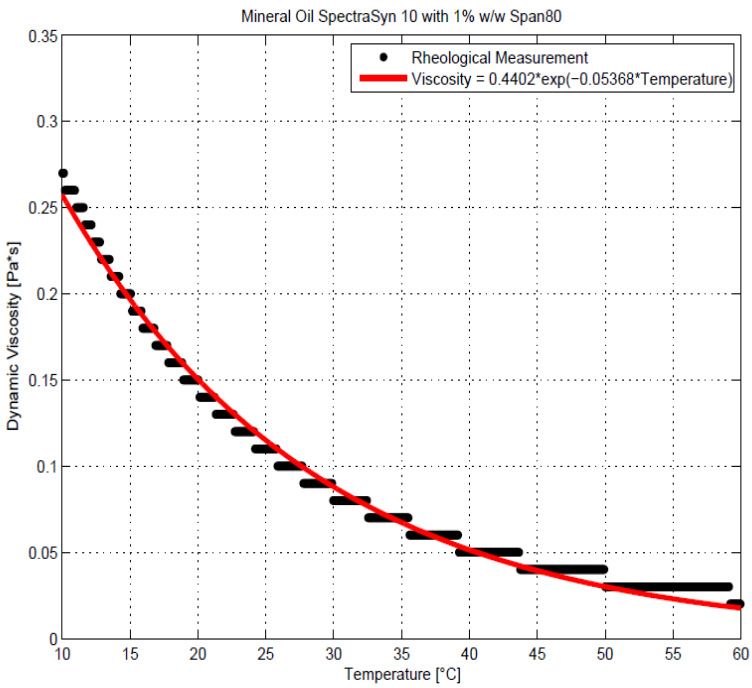
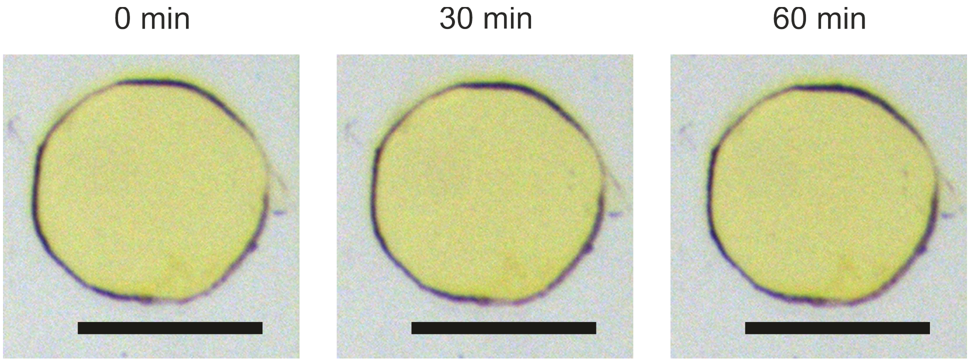
S1: Rheological measurements of the dynamic viscosity of the used mineral oil at various temperatures with 1% w/w detergent Span80

Measurements were conducted with Anton Paar MCR 301 (Anton Paar, Graz, Austria) rheometer using a cone/plate measurement geometry (49.964 mm diameter, cone opening angle 0.995°). The temperature was varied from 10°C to 60°C with a constant applied shear rate of 100 s^{-1}.



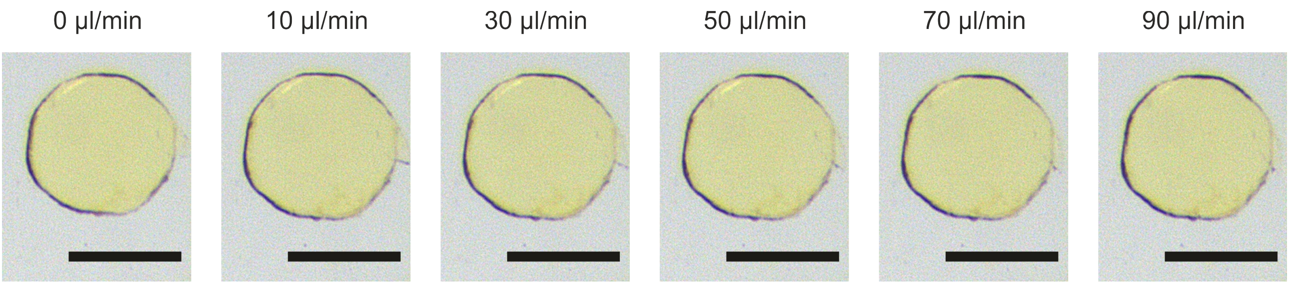
S2: Observation of swollen hydrogel behaviour over time

A swollen hydrogel was observed in an oil filled channel for 1 hour. We found no altering in the hydrogel size or structure indicating a stability long enough for microfluidic application.
(black bar = 500 µm)



S3: Hydrogel behaviour at various flow rates without conducted heating

A swollen hydrogel was observed in an oil filled channel at various oil flow rates. Heating was not conducted so that no water reservoir by the expelled water was formed. The pictures show that without heating no water-in-oil droplets can be formed and that the hydrogels are also mechanically stable even at high flow rates causing high shear rates and therefore mechanical stress.
(black bar = 500 µm)



S3: Hydrogel behaviour at various flow rates without conducted heating

To calculate the stored water volume in a swollen hydrogel, previous studies were performed to find an assumption which allows to estimate the height of a shrunken hydrogel. A relation was found between the hydrogel side expansion which can be observed in a top view and the altering in the height during the swelling process. Important to note is that the hydrogels in the previous studies were also covalently attached to the surface by silanisation and photopolymerisation.
In previous studies we observed hydrogels covalently attached to glass surface in a side view under a microscope (see pictures below, black bar = 250 µm). We measured the height and the width after swelling and after shrinking. We made the following assumption in the script:

$$Q=\frac{A_{swollen}}{A_{shrunken}}=\frac{h_{swollen}}{h_{shrunken}} \quad (1)$$

This assumption was made for the top-view of an hydrogel and is translated to the side-view in the following way:

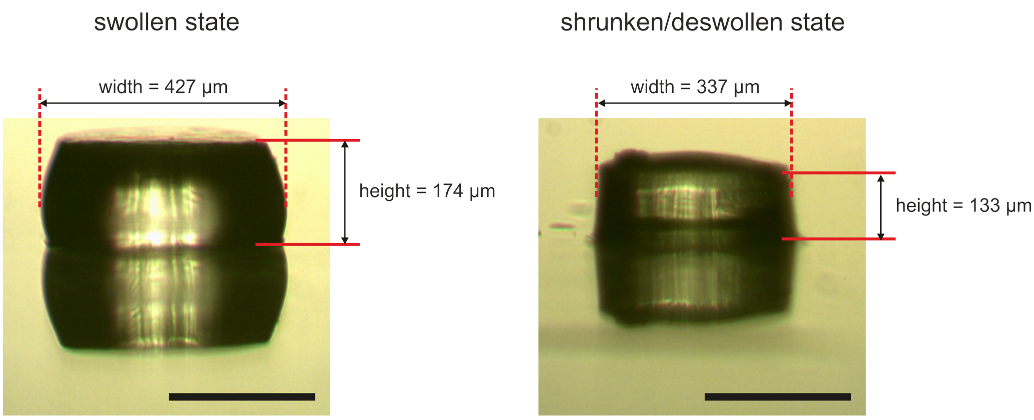
$$Q=\frac{w_{swollen}}{w_{shrunken}}=\frac{h_{swollen}}{h_{shrunken}} \quad (2)$$

For showing the validity of the assumption the height after shrinking is calculated with equation (2) and compared with the measured height :

$$h_{shrunken}=\frac{h_{swollen} * w_{shrunken}}{w_{swollen}} \quad (3)$$

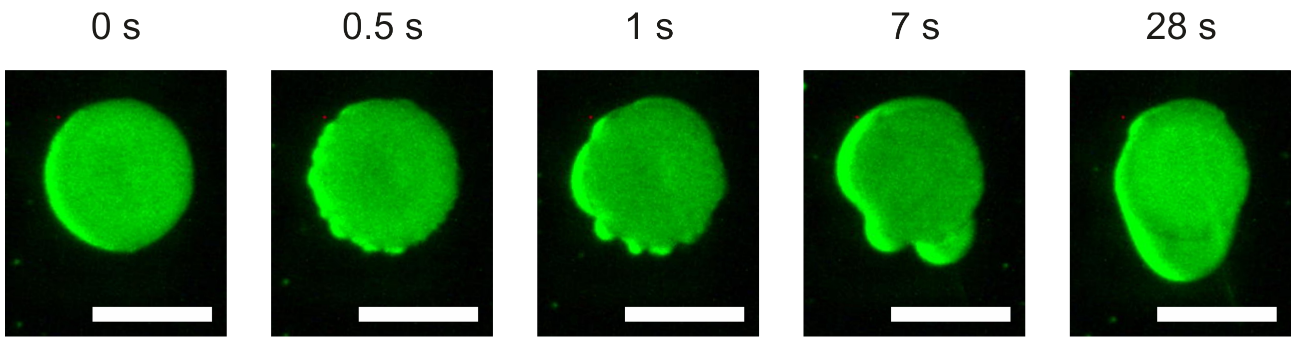
$$h_{shrunken}=\frac{174\,\mu m * 337\,\mu m}{427\,\mu m}=137\,\mu m$$

By comparing the measured height after shrinkage (= 133 µm) and the calculated height (= 137 µm) it becomes clear that the assumption for estimating the hydrogel height after shrinkage is valid.



S4: Hydrogel shrinking and water reservoir forming process for droplet dispensing

For the device operating time which is the time required for hydrogel swelling and droplet releasing (including hydrogel deswelling and water reservoir formation) we stated that the device limiting step is the hydrogel swelling process. In the pictures below we show how fast the hydrogel deswelling process and water reservoir formation is (time duration around 30 seconds) compared to the swelling process time (time duration around 11 minutes for a 400 µm diameter hydrogel). The time duration starting with the initiated heating by the operator (at 0 seconds) is noted each images top. (white bar = 500 µm)



Supplementary Movies:

Supplementary movie 01:

Supplementary movie 01: captured swelling process of a 800 µm hydrogel using a standard camera through the eyepiece of the microscope (frame rate of 19 fps) including image processing results.