Stimuli-controlled fluid movement at the microscale

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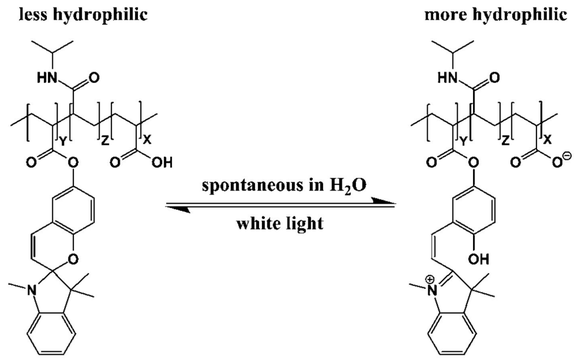
Introduction

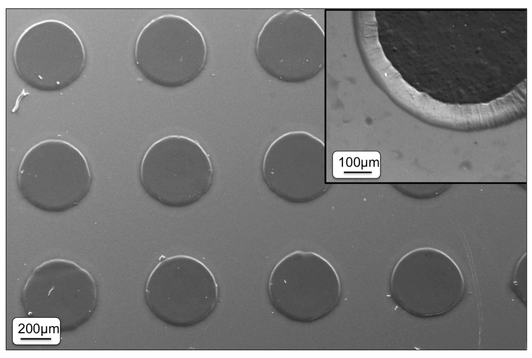
Integrating stimuli responsive materials into the system provides external control over fluid flow and can reduce the over-all complexity of the device. In this work we present two main approaches for stimuli controlled fluid movement at the microscale. The first approach is to use photo-actuated hydrogels which shrink when exposed to white light; these gels can then be incorporated in microfluidic devices as micro valves. The second approach is to use stimuli-controlled synthetic micrometre sized droplets which move across the interface of aqueous solutions.

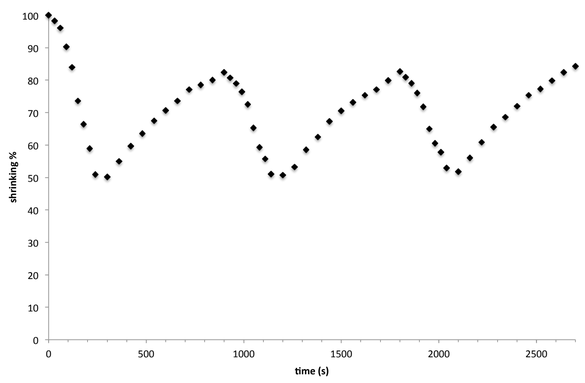
Photo-actuated hydrogels

Actuation mechanism

Actuator p(NIPAAm-*co*-SP-*co*-AA) micro-structured hydrogels were photo-polymerised through micro-patterened masks. Their photo-induced shrinking and reswelling mechanism was studied under white light irradiation and in the dark, respectively.

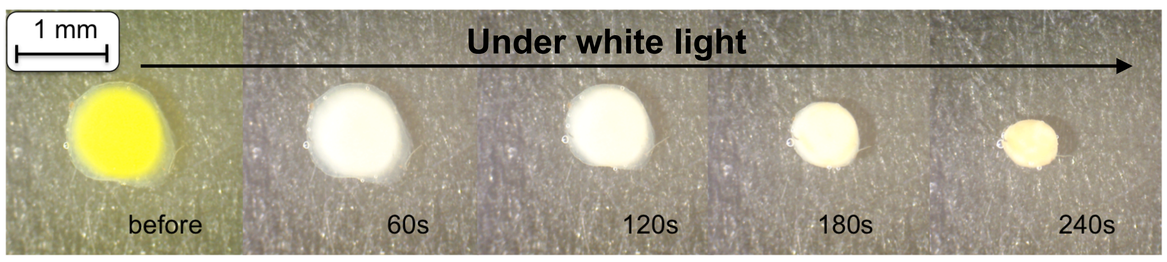


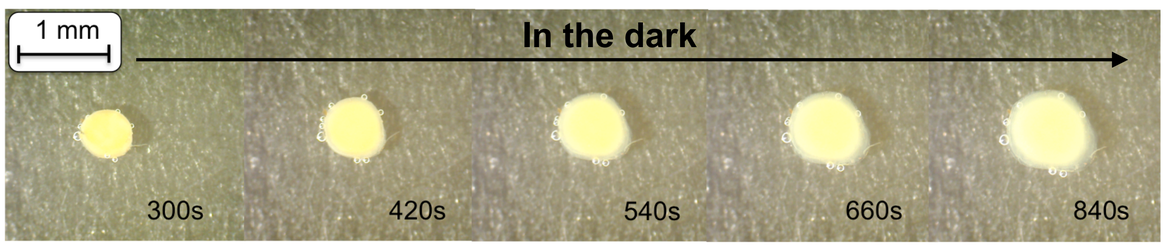




Reversible actuation

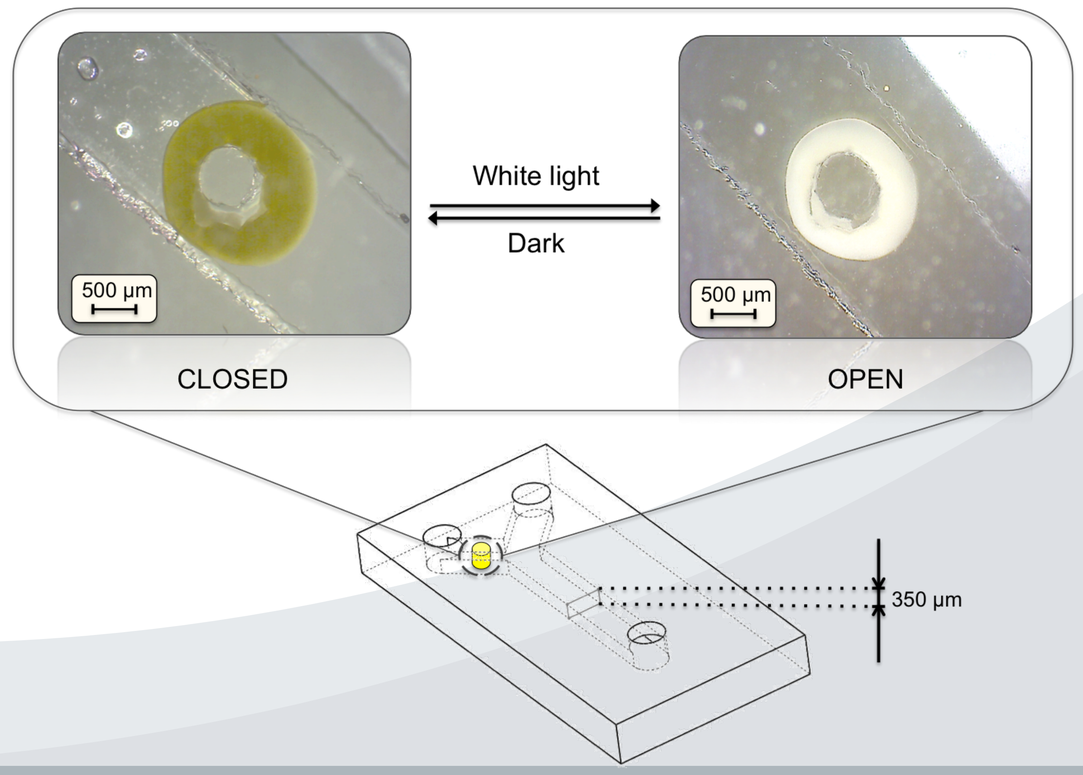
The hydrogels reach 50% of the fully hydrated size after 4 min. of white light irradiation. After the removal of the white light the hydrogel re-swelled to 84% of the fully hydrated size after 11 min. This shrinking and re-swelling cycle can be repeated with great reproducibility.





Hydrogel valve application

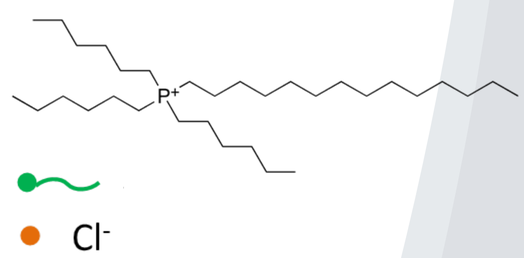
Hydrogel microstructures were photo-polymerised *in-situ* inside PDMS/ glass microfluidic channels. Exposure to white light causes the valves to contract thus opening the channel, allowing fluid to flow. The opposite was seen when the valve was kept in the dark. These hydrogels can be successfully used as photo-controlled valves in microfluidic systems for repeatable ON/OFF flow modulation in neutral environments.

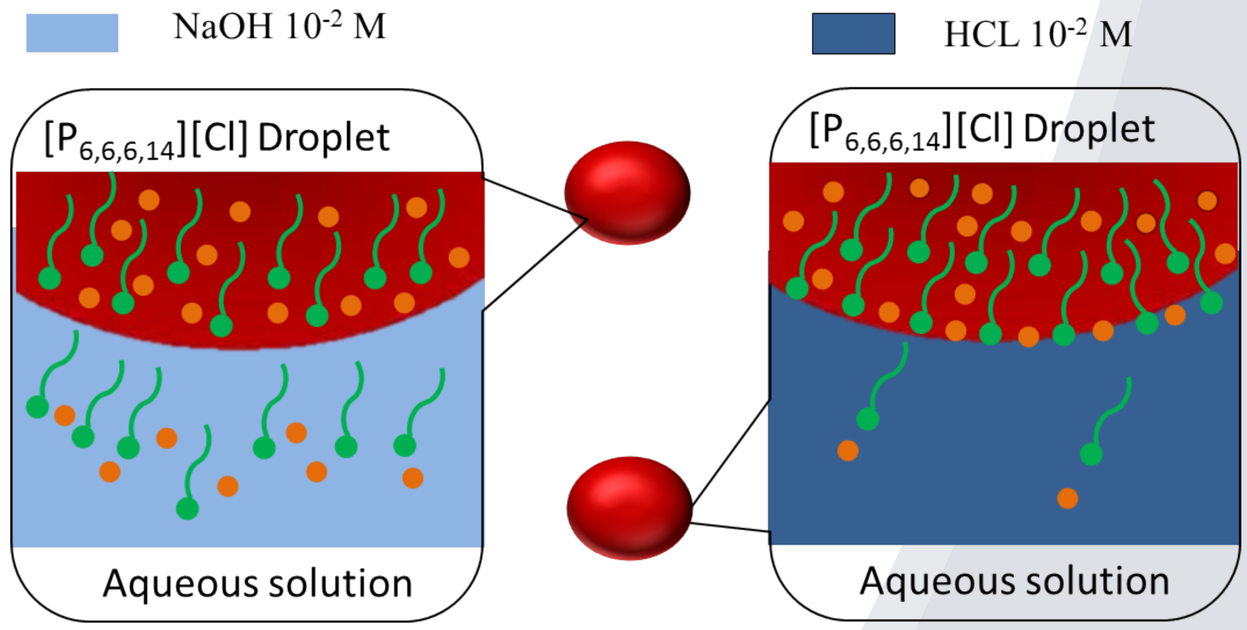


Stimuli-controlled synthetic micrometer sized droplets

Droplet composition

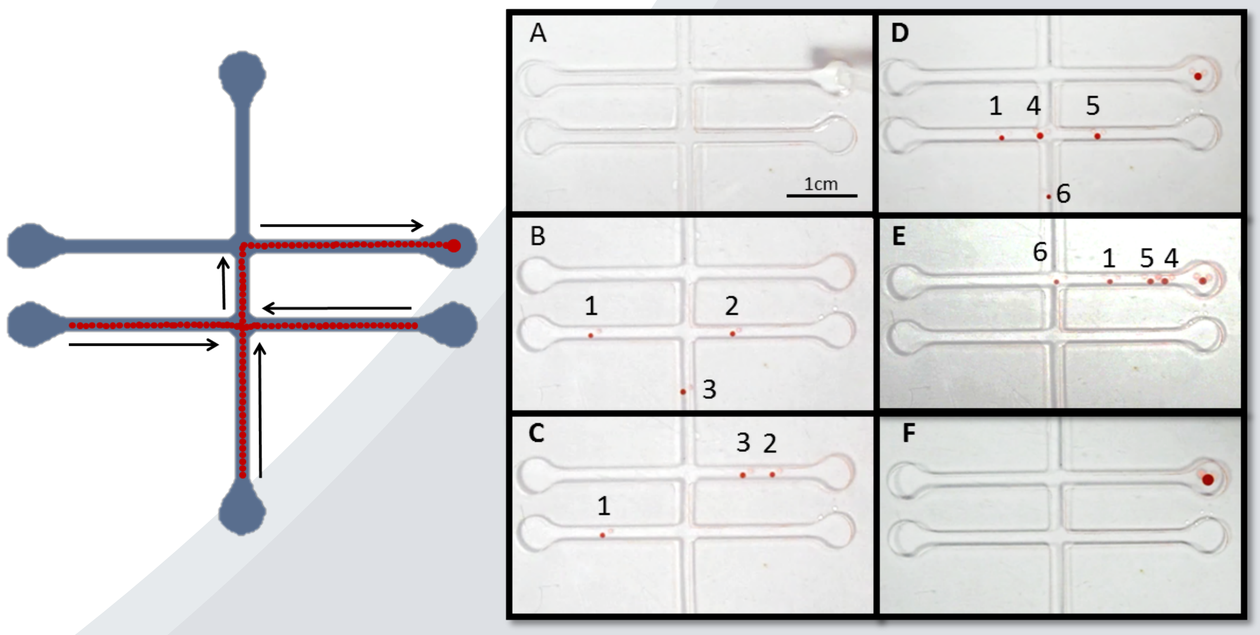
These single component droplets are composed of an Ionic liquid, namely Trihexyl(tetradecyl)phosphonium chloride ([$P_{6,6,6,14}$][Cl], with a small amount of red dye for visualization. The $[P_{6,6,6,14}]^+$ is a very efficient cationic surfactant. Once released the $[P_{6,6,6,14}]^+$ cation will lower the surface tension of the aqueous solution.





Droplet movement

The motion of these discrete droplets was controlled by the triggered release of the $[P_{6,6,6,14}]^+$ surfactant. Solubility of the $[P_{6,6,6,14}]^+$ is dependant on Cl^- concentration in the aqueous solution. In this work the droplets were guided to specific destinations in open fluidic channels of different configurations through the use of chemoattractants such as NaCl or HCl.



Powered by light?

Photo-control of the droplets can be achieved by the incorporation of photo-acids into the aqueous solutions. Photo acids such as acidified spiropyrans or 2-nitrobenzleadehydes can be used to photo-induce pH gradients. Photo actuated hydrogels can also be used for triggered release of chemoattractants.

Conclusions

Incorporation of stimuli-controlled synthetic systems in microfluidic devices offers unprecedented versatility and external flow control. We envision using these systems to create a new generation of sustainable, low-cost, externally-controlled and self-reporting fluidic systems.

Acknowledgments

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