Stimuli-controlled movement of droplets and polymeric “vehicles”

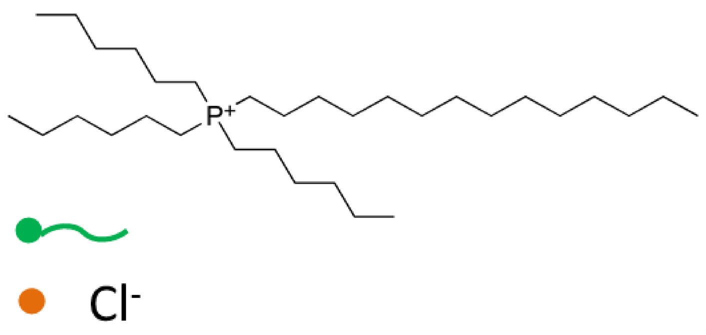
Wayne Francis, Larisa Florea* and Dermot Diamond
Insight Centre for Data Analytics, National Centre for Sensor Research, School of Chemical Sciences, Dublin City University, Ireland.

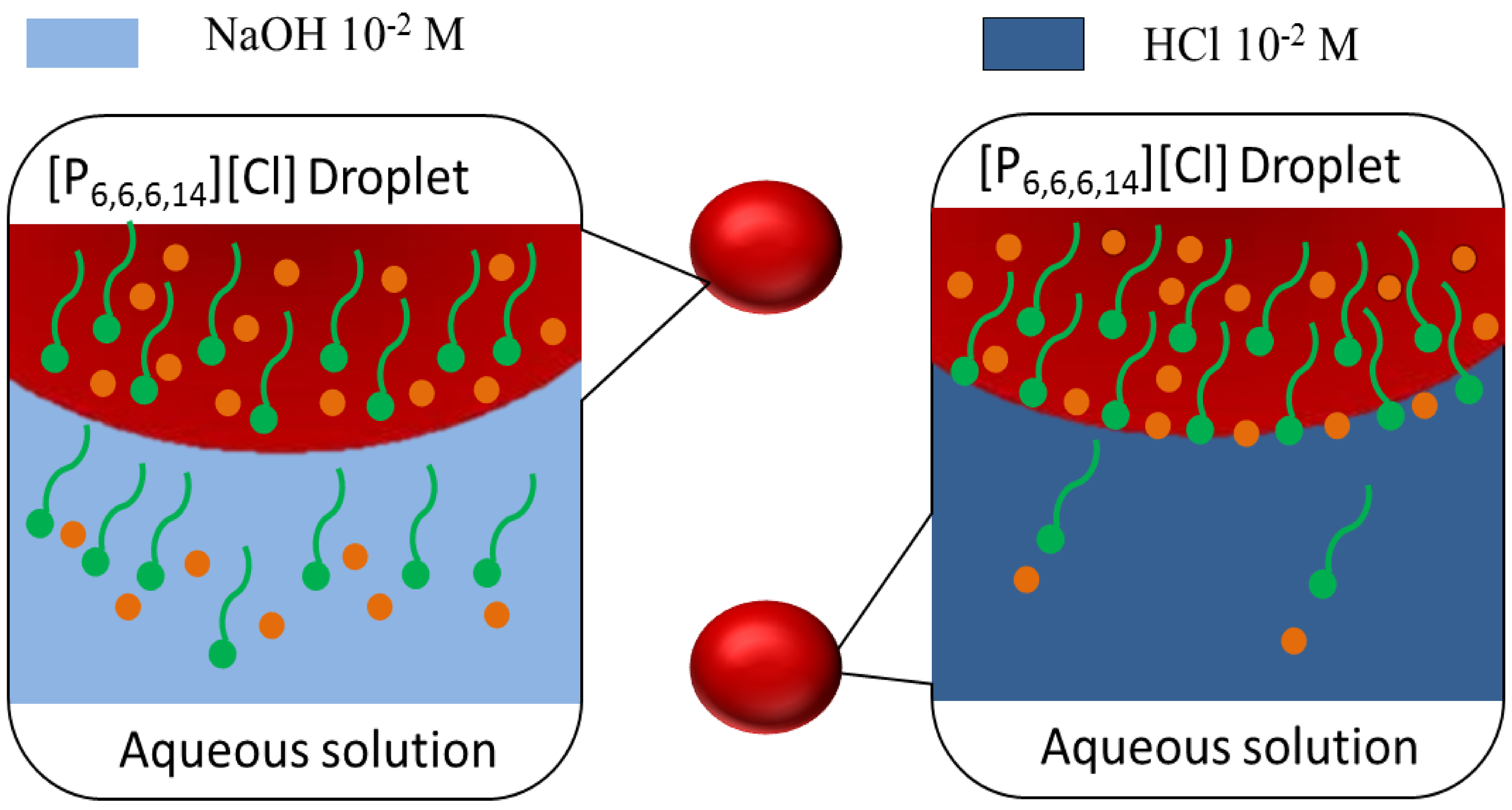
Introduction

Stimuli-responsive materials have gained much attention recently as new means for fluid flow control within the field of microfluidics. The ability to control of droplets and polymeric “vehicles” in a contactless manner within microfluidic chips offers new and exciting possibilities such as directed transport of molecular cargo to desired destinations and dynamic sensing of the fluidic environment during movement.

Droplet composition

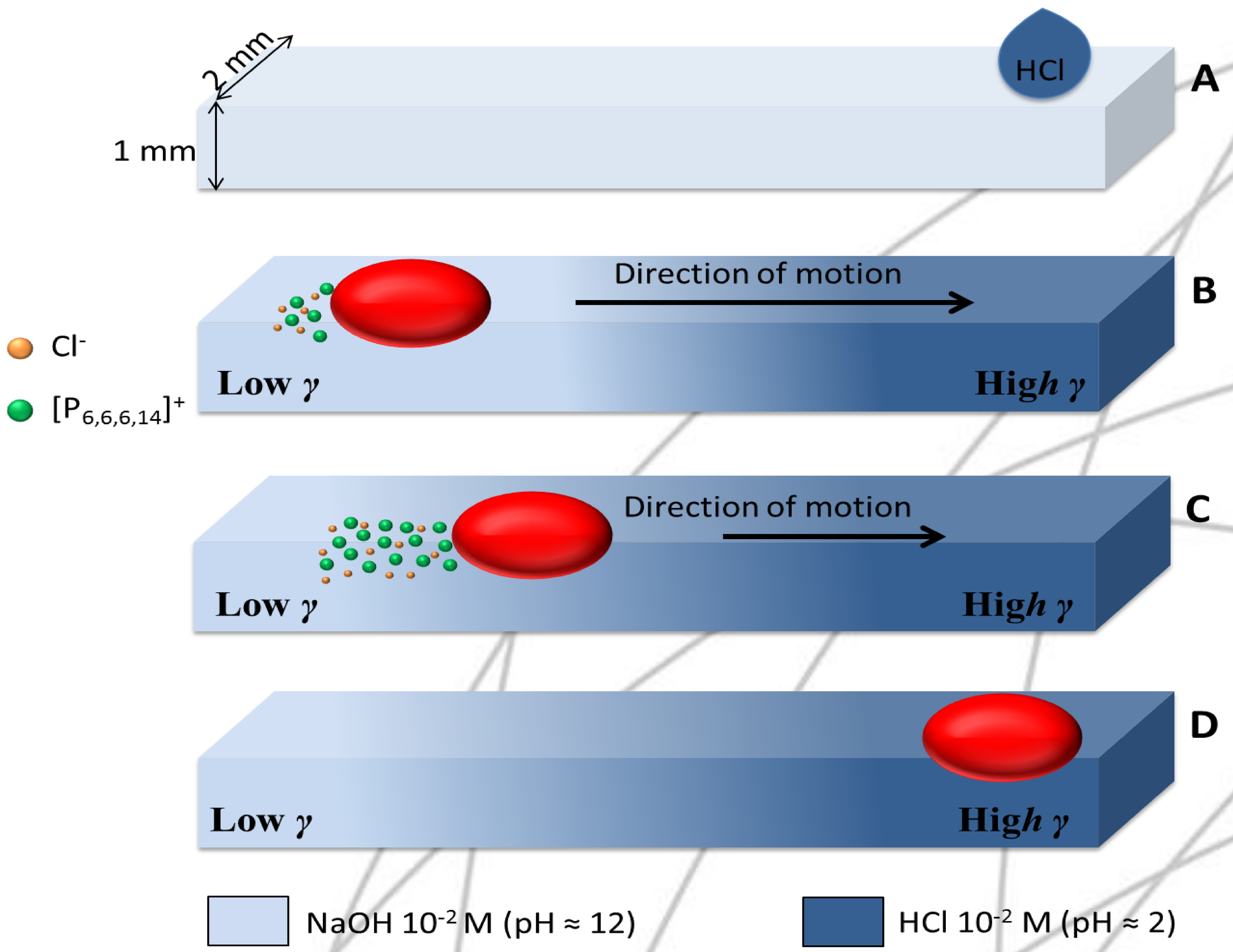
In this work single component droplets composed of an Ionic Liquid, namely Trihexyl(tetradecyl)phosphonium chloride $[P_{6,6,6,14}][Cl]$ were developed. The $[P_{6,6,6,14}]^+$ is a very efficient cationic surfactant. Once released the $[P_{6,6,6,14}]^+$ cation will lower the surface tension of the aqueous solution.





Droplet movement

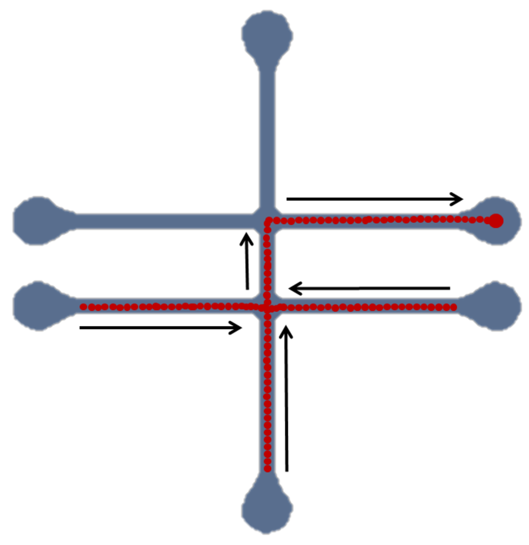
The motion of these discrete droplets was controlled by the triggered release of the $[P_{6,6,6,14}]^+$ surfactant. In this work, the droplets were guided to specific destinations in open fluidic channels of different configurations through the use of chemoattractants such as NaCl or HCl.

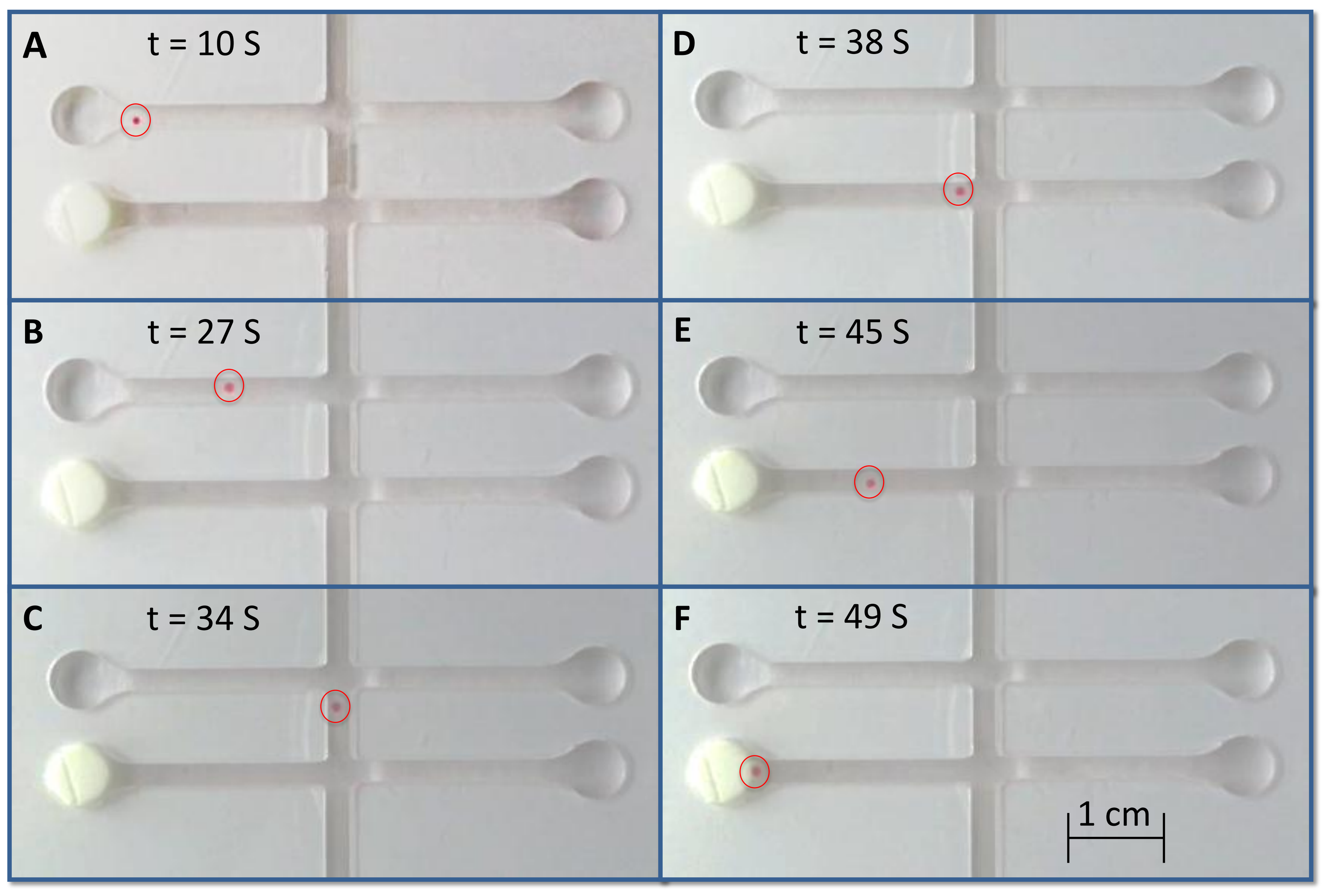


The surface tension gradient is created by the asymmetric release of $[P_{6,6,6,14}]^+$ from the IL droplet into the aqueous phase. The rate of $[P_{6,6,6,14}]^+$ release depends on the concentration of the Cl^- in the aqueous solution. The free $[P_{6,6,6,14}]^+$ (the active surfactant at the air-aqueous interface) is formed through dissociation of the relatively closely associated $[P_{6,6,6,14}][Cl]$ ions in the IL and depends on the local Cl^- concentration at the IL-aqueous boundary.

Single droplet manipulation

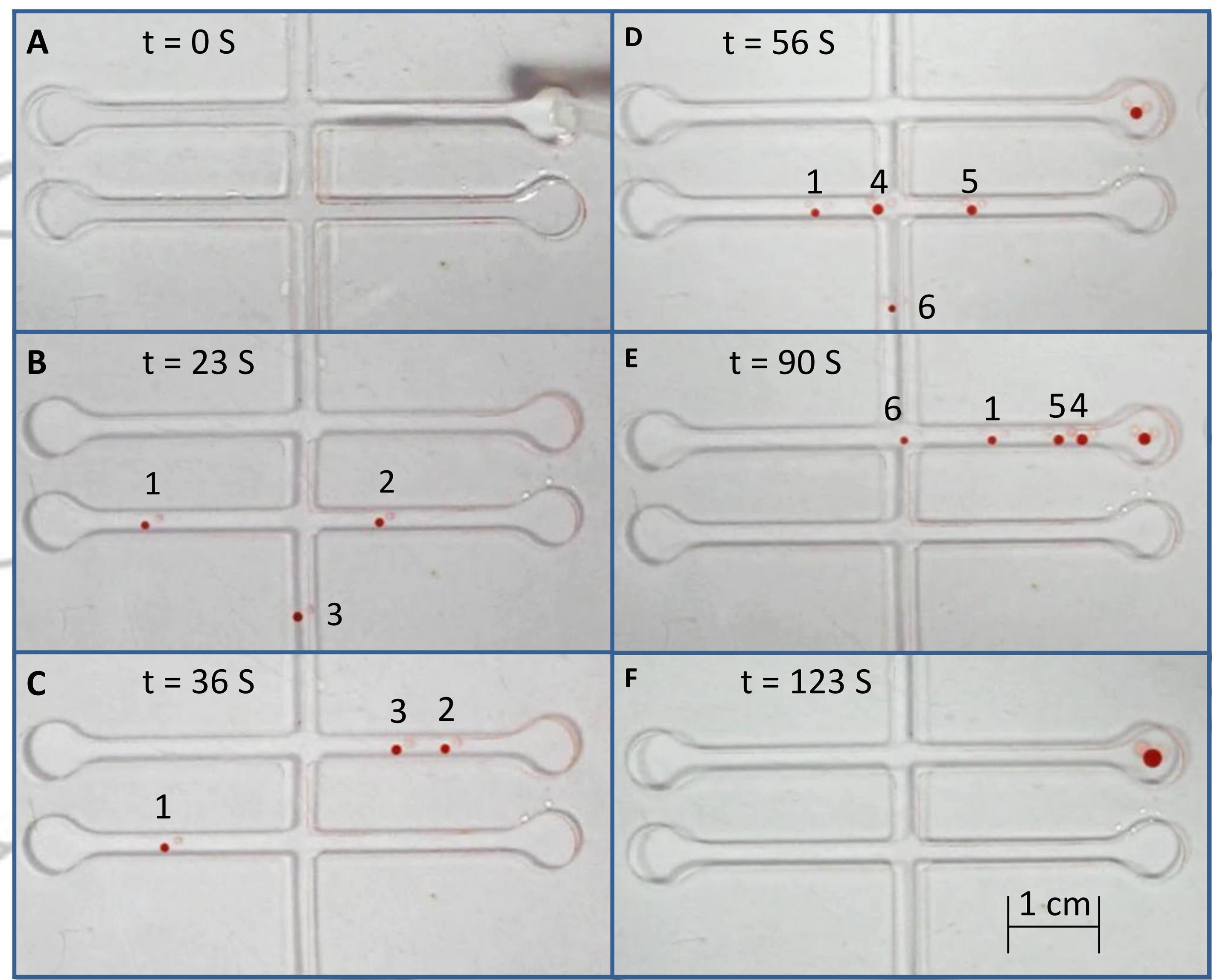
Controlled moved of a single droplet was achieved by initially filling the channels with a solution of 10^{-2} M NaOH. An acrylamide gel previously soaked in a solution of 10^{-2} M HCl was then placed at the desired destination.





Multiple droplet manipulation

Controlled movement of multiple droplets was achieved by filling the channels with a solution of 10^{-2} M NaOH and then placing two – three drops of a solution of 10^{-2} M HCl at the desired destination.



Polymeric vehicles

Polymeric vehicles were synthesised by polymerising a polyacrylamide gel in an ionic liquid. This synthesis produced an ionogel which would move spontaneously when placed in a solution of 10^{-2} M NaOH or deionsed water.

Conclusions

Incorporation of stimuli-controlled synthetic droplets and “vehicles” 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

Science foundation Ireland under the Insight initiative, grant SFI/12/RC/2289.