

Self-Propelled Ionic Liquid Droplets

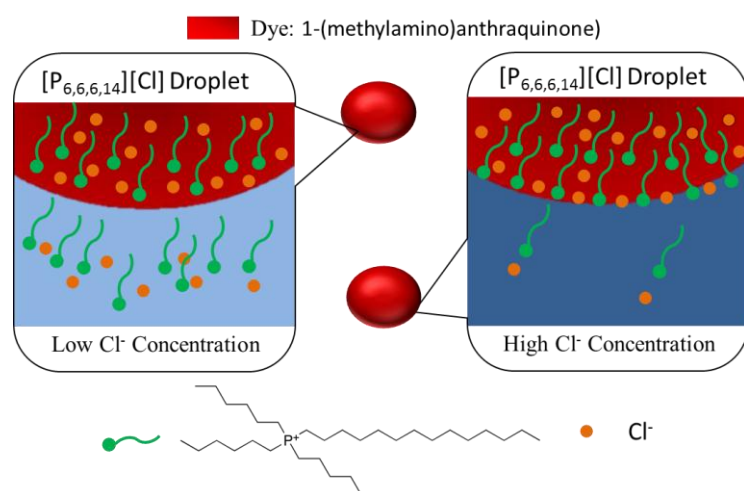
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Stimuli-Controlled Fluid Movement

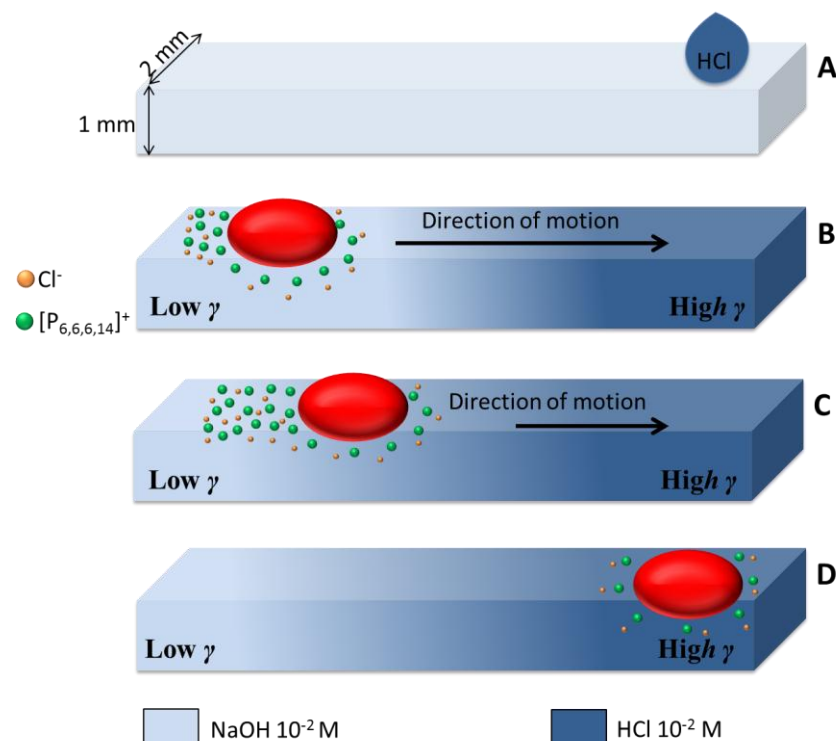
Stimuli-responsive materials have gained much attention recently as new means for fluid flow control within the microfluidic field. Controlling flow using conventional pumps, valves and other physical actuators can be costly and offers limited control over flow within the chip. Flow can be potentially controlled by integrating stimuli-responsive droplets into the system. This provides external control over fluid flow and allows for interesting advantages such as the potential for the droplets to act as dynamic sensing vehicles, micro-chemical reactors and micro-cargo carriers. In this work stimuli-responsive novel self-propelled droplets capable of moving at the air/liquid interface are developed and characterized.

Droplet Composition and Movement

The micro-meter sized droplets used in this project were designed to move in an open fluidic channel and were composed of the ionic liquid (IL) Trihexyl(tetradecyl)phosphonium chloride ($[P_{6,6,6,14}][Cl]$). The motion of these droplets was controlled by the triggered release of the $[P_{6,6,6,14}]^+$ cation, a component of the IL and a very efficient cationic surfactant.

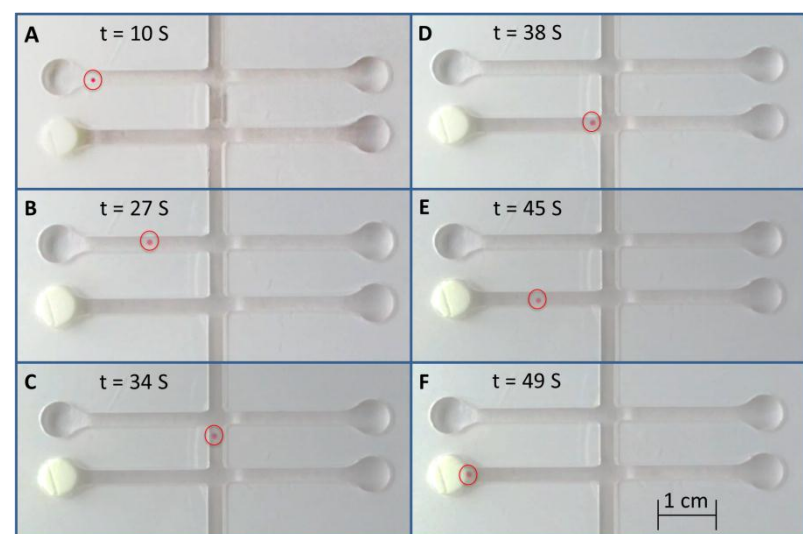


Once released, the surfactant lowers the surface tension of the aqueous solution, thus creating an asymmetric surface tension gradient. This leads to Marangoni like flows which drive the droplet from areas of low surface tension toward areas of high surface tension.



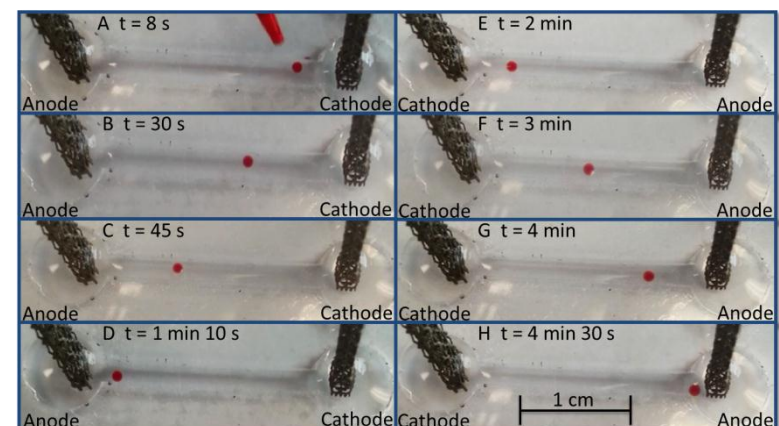
Example of Droplet Movement

Controlled movement 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.



Electro-Guided Droplet Movement

To date, the methods for generating the Cl^- gradients have been relatively short lived due to chemical equilibrium. This limits the control over the speed of the droplet and the amount of time the droplets can be manipulated. Electro-generation of Cl^- gradients is proposed as this will potentially allow for on demand gradient generation, while also maintaining the gradients for longer periods of time.



Possible Applications

In principle, this effect could facilitate many applications involving smart materials, such as programmed drug delivery from patches through skin, smart wearable fabrics that respond autonomously to changes in the local environment (e.g. body temperature), or the realization of very low cost/low power (ideally zero power) autonomous chemical analysers capable of performing sophisticated microfluidic management using chemistry to drive the processes, rather than conventional pumps and valves.

Conclusion

Incorporation of stimuli-controlled synthetic droplets 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. The use of electro-stimulus allows on demand generation of gradients within microfluidic devices, which broadens the potential application of these self-propelled droplets.

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