Stimuli-controlled fluid movement at the microscale

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The integration of stimuli-responsive materials into microfluidic system provides external control over fluid flow and can reduce the over-all complexity of the microfluidic device [1, 2]. In this work, we present two main approaches for stimuli-controlled fluid movement at the microscale. The first approach comprises the use of photo-actuated hydrogels as micro-valves, while the second approach involves stimuli-controlled movement of synthetic micrometre size droplets.

1. Photo-actuator hydrogels were developed using copolymers of *N*-isopropylacrylamide, acrylated spiropyran and acrylic acid. In water, the acrylic acid comonomer dissociates, resulting in the protonation of the photochromic spiropyran (SP) to protonated merocyanine ($MC\text{-}H^+$). This form is hydrophilic, allowing the hydrogel to swell. Exposure to white light promotes isomerisation of the $MC\text{-}H^+$ form to the hydrophobic SP form, which triggers contraction of the hydrogel. In this manner, reversible photo-control over the volume of the hydrogel was achieved. It was found that different polymerization solvents directly influenced the morphology of the resulting hydrogels, and in particular, the porosity. This in turn influences the diffusion pathlength of water into/out of the gel, which has a dramatic impact on the swelling and shrinking kinetics of the hydrogel. Microstructures composed of optimised hydrogels were photopolymerised within microfluidic channels, and their application as photo-controlled valves demonstrated.

These photo actuators are of great interest as they can be controlled using light, in a noncontact manner. They are also of great interest for biological applications as they can operate in neutral solutions, in contrast to previous formulations [3].

2. For the second approach, micrometre size droplets were designed to move in an open fluidic channel. The motion of these discrete droplets was controlled by the triggered release of surfactant molecules, which were contained within the droplet. Once released, the surfactant altered the surface tension of the aqueous phase. As the solubility of the droplet-contained surfactant varied with the pH of the aqueous solution, these droplets were guided to specific destinations in fluidic channels through the use of pH gradients. These gradients can be created on demand within microfluidic channels using light due to the photoconversion of sulphonated (water soluble) $MC\text{-}H^+$ to SP. This increases the local acidity due to the release of free protons from $MC\text{-}H^+$, which triggers the release of surfactant, and stimulates the photo-controlled movement of the droplets.

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